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FULL-SCALE TESTS ON THE RESPONSE OF ICE STRENGTHENED PROPELLER BLADES TO ICE LOADS

Volume I: Data Collection Report

Prepared for

Transportation Development Centre
Policy and Coordination Group
Transport Canada

by

GEOTECHnical Resources Ltd.

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VOLUME 1: DATA COLLECTION REPORT

by:

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March, 1989

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16. Abstract

Propellers on ice-going vessels break due to ice forces. A propeller test program consisted of loading a 2600 kg Cunial bronze blade from the Canmar Kigoriak. It was mounted on a reaction frame and three servo-controlled hydraulic actuators forced a 1.3 m diameter by 0.75 m thick block of fresh water ice onto the blade at speeds from 3 mm/s to 100 mm/s. The applied load (3 locations) blade strain (14 locations), blade deformation (3 locations) and local interaction pressure (5 locations) were recorded. The blade was loaded normal to it's surface until permanent deformation occurred. A load of 1 MN applied near the blade tip produced minor plastic deformation near the blade tip. The ultimate blade load capacity according to the manufacturer was 1.8 MN. Tests at 100 mm/s created a brittle ice failure mode, tests at 3 mm/s produced ductile ice failure. The largest loads occurred during the slow tests. Two tests used wood instead of ice, the results were similar to the slow speed ice tests. The engineering significance of the tests is that blade stiffness as well as blade strength are both important. The current blade regulations do not incorporate the results of this study.

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16. Résumé

Les hélices des cargos brise-glace cèdent parfois aux sollicitations exercées par les glaces. Des essais de choc ont été menés sur une pale d'hélice en bronze Cu-Ni-Al pesant 2 600 kg, prélevée sur l'hélice du Canmar-Kigoriak. Les essais ont eu lieu sur un bâti construit exprès, comportant un actionneur hydraulique asservi, à trois têtes, qui a permis d'appuyer un bloc de glace d'eau douce de 1,3 m de diamètre sur 0,75 m d'épaisseur sur l'intrados de la pale, à des vitesses comprises entre 3 et 100 mm/s. Les efforts dynamométriques (3 endroits), les contraintes (14 endroits), les déformations (3 endroits) et les pressions localisées (5 endroits) ont été mesurés et enregistrés. La charge a été appliquée normalement à la surface de la pale au point de provoquer une déformation permanente. Une charge de 1 MN près du bout de la pale y a provoqué une légère déformation plastique. Selon les fabricants, la charge maximale que peut supporter la pale est de 1,8 MN. Les essais de choc à des vitesses de 100 et de 3 mm/s ont provoqué la rupture fragile et celle ductile de la glace. Les charges les plus élevées ont été observées aux vitesses les plus basses. Deux essais utilisant du bois plutôt que de la glace ont donné des résultats analogues aux essais avec la glace aux vitesses faibles. Pour l'ingénieur, les résultats montrent l'importance qu'il faut donner à la raideur de la pale aussi bien qu'à sa résistance. La réglementation en vigueur se rapportant aux pales d'hélice ne tient pas compte des résultats de la présente étude.

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SUMMARY

Regulatory bodies, ship designers and ship operators are all concerned with a variety of damage to vessels. There are many situations where damage can occur to propellers. A particularly severe case is the following. In order to reverse the direction of motion of a vessel with a fixed pitch propeller the rotation of the propeller shafting has to be reversed. During this reversal, a critical period occurs in which the shaft is stopped but the vessel may still be moving. If the ship or, more significantly, the blade contacts a massive piece of ice, the blade may break.

In this project we took an ice-strengthened bronze propeller blade from the Canmar Kigoriak and instrumented it for testing. A non-destructive series of tests on the blade revealed a crack system in the root of the blade. Subsequently, the blade was rammed into hard fresh water ice and the forces, pressures and reactions were measured. Some tests were conducted when the blade was permanently deformed.

A steel reaction frame and blade tie-down assembly was designed and constructed. It was designed to withstand approximately 2.5 MN applied to the blade tip, at the relative radius 0.9 and 0.5 m off from the centre line. A triple high speed actuator assembly pushed a containment vessel full of ice into the blade surface. Speeds between 3 and 100 mm/s were achieved which directly simulate the situation of the fixed pitch propeller hitting a massive ice feature. The applied loading and block reaction were monitored by a series of installed transducer systems and recorded via a digital data acquisition system.

The loads from each actuator were determined by recording the hydraulic oil pressure. Strain gauges were placed at strategic locations on the blade surface and recorded blade strains. While the blade material is still elastic, these data can provide measures of the blade stress. As one of the aims of the project was to produce permanent deflection in the blade, these gauges were also used to determine load levels at which the blade went plastic. The set of displacement gauges recorded the out of plane blade deflection, both elastic and plastic. A set of sensors recorded the ice/blade interaction pressures within the interaction zone.

In order to permanently deform the blade, the tests indicated that the displacement available from the actuators was the limiting factor rather than available load capacity. For this reason, wood was used instead of ice as the impact medium for two tests. Additionally, two hammer tests were conducted which recorded the free vibration modes of the propeller blade. The test results are summarized in Table 1.

TABLE 1

SUMMARY OF ICE IMPACT TESTS

TEST No.	ICE TYPE	ICE COND'N	CONTACT SHAPE ICEFOOT	SURFACE AREA m^2	SPEED mm/s	MAX. LOAD MN	LOCATION	COMMENTS	STRAINS
1	Blocks	New	Rectang.	1.00	91.5	0.66	Center	2 Load Peaks	Elastic
2	Crushed	New	Circular	1.54	85.7	0.53	Center		Elastic
3	Crushed	Used	Circular	1.20	83.3	0.53	Center		Elastic
4	Crushed	Used	Polygon	0.68	100.0	1.03	Center	2 Load Peaks	Elastic
5	Crushed	New	Triang	0.60	100.0	0.37	Center	2 Load Peaks	Elastic
6	Crushed	Used	Polygon	0.10	101.5	0.57	Center		Elastic
7	Crushed	New	Circular	0.38	102.7	0.37	L. Edge	2 Load Peaks	Elastic
8	Crushed	New	Circular	0.68	100.0	0.53	L. Edge	2 Load Peaks	Elastic
9	Crushed	New	Circular	1.25	100.7	1.28	L. Edge	2 Load Peaks	Plastic
10	Crushed	Used	Circular	0.91	102.9	0.42	L. Edge		Elastic
11	Crushed	Used	Circ/Res	0.91	100.7	1.13	L. Edge	2 Load Peaks	Elastic
12	Crushed	New	Circular	1.25	100.7	1.27	L. Edge		Elastic
13	orted								Elastic
4	Crushed	New	Circular	1.25	3.0	1.75	L. Edge	Ductile	Plastic
15	Crushed	Used	Polygon	0.60	5.5	3.93	L. Edge	Ductile	Plastic
16	Free Vibration Test						T. Edge		Elastic
17	Free Vibration Test						Center		Elastic
18	Timber	New		0.30	103.5	2.05	L. Edge		Plastic
19	Timber	Used		0.30	102.7	2.40	Bucket	Collapsed	Plastic

The vast amount of data collected in the experiment was inspected and the dominant characteristics were extracted:

1. The center part of the blade attracts more load than the edge; hence, the point of application of the load gravitates towards the centerline of the blade.

2. The point of application of the loads corresponds closely to the ones observed in full scale tests.

3. The maximum load pressures recorded during these tests was 28.20 MPa during test PBT15.

4. Two types of pressure build-up are identified - ductile and brittle

5. The maximum load recorded was in the same test that produced the maximum local pressures (Test PBT15).

6. At the leading edge, blade displacements of about 57 mm are needed to cause plastic deformations.

7. For the ductile type of tests, 71% of the input energy went into the blade.

8. For brittle type of tests, most of the input energy went into the ice crushing and extraction.

9. At an applied load of about 1 MN, all load/strain curves start deviating from the linear relationship.

10. At the stress level of 200 MPa, plastic flow of the material was registered.

The various observations on the interaction and on the response of the blade to the loading was critically reviewed in terms of the engineering significance of the tests. These important conclusions are summarized below.

1. The blade of the shrouded CPP propeller was found to be very strong in terms of the ultimate load it was able to carry with complete destruction 3.95 MN. This is more than twice the 1.838 MN stated as a blade collapsing load by the propeller manufacturer.

2. At that load level, the blade residual deformation near the leading edge was significant (40 mm), but localized and the blade was considered to be still operational perhaps at reduced RPM.

3. Although a number of high loads were applied, there was no evidence of brittle behaviour. This means that the existing crack near the blade root was probably caused by cyclic loading of low amplitude for example hydrodynamic or inertial loads and not by the individual high loads coming from direct contact with the ice. The crack is located on the compression side.

4. The issue of blade suitability for service is not based on the ultimate load it can carry, but on the geometry of the deformed blade and its influence on blade performance and vibration levels in that condition. Therefore, this is an issue of the stiffness of the blade sections, rather than their strength.

5. More than half of the strain energy of the blade goes into the plastic deformation. This shows that the plasticity of the blade is a blade protection mechanism and should be considered in modelling of the blade response to high loads.

6. The existing models of ice/propeller blade interactions do not reflect the results of the test performed. New developments are needed in this field.

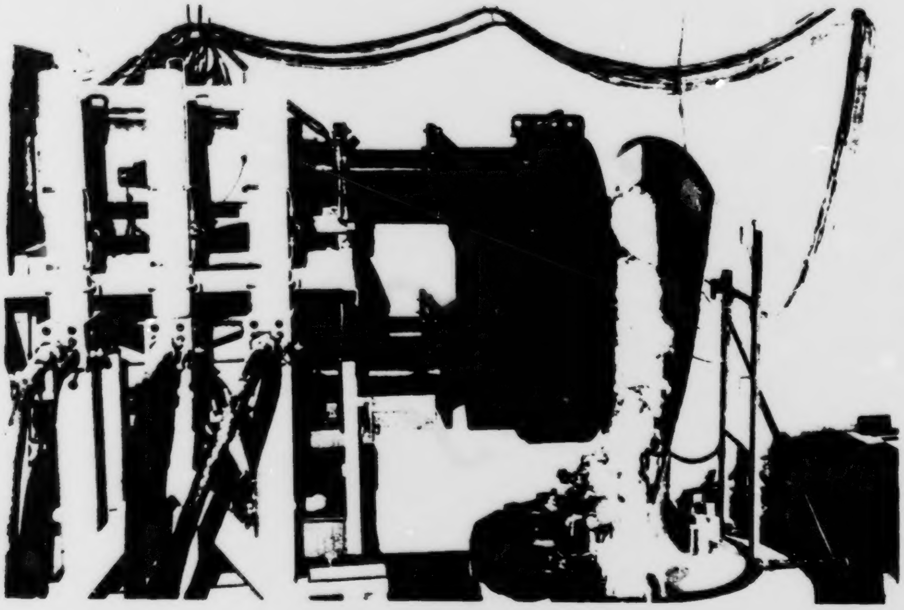
We recommend that:

1. A model of ice/blade interaction be developed and implemented, reflecting the wealth of new information collected.

2. A comparison of test data with field data be carried out for the purpose of explaining the cause of propeller damages.

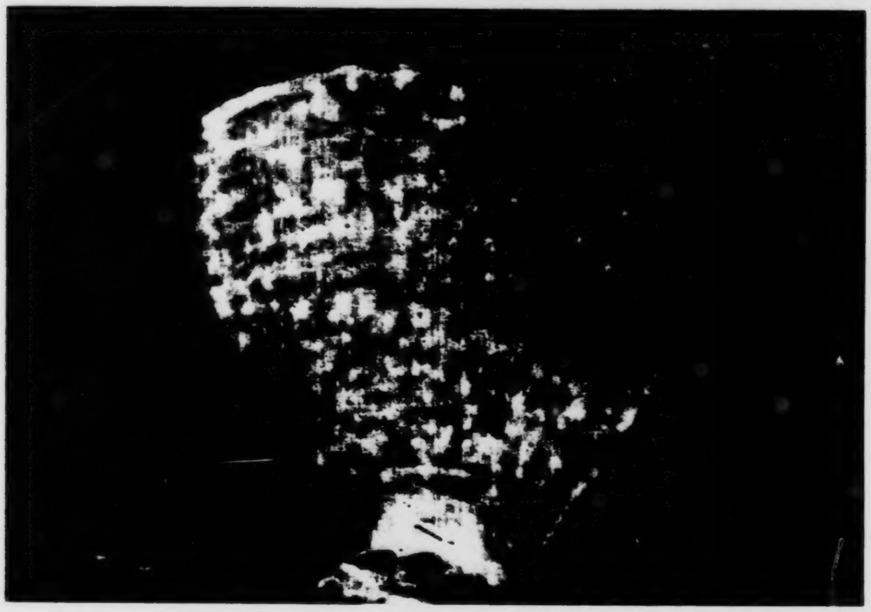
3. A material-oriented experimental study be carried out to determine the plastic, ultimate and fatigue properties of various propeller blade materials in order to establish the causes of the existing blade failures.

4. An analysis of the test data with respect to their application to Arctic Shipping Pollution Prevention Regulations, the strength/stiffness issue, blade be carried out.



Experimental Set-Up

Dispositif Experiment



Propeller Blade

Helice

SOMMAIRE

L'endommagement des navires est un sujet qui préoccupe beaucoup tous les corps intéressés: architectes navals, armateurs et instances réglementaires, et en particulier l'endommagement des hélices qui peut survenir dans un grand nombre de cas. Le cas le plus préoccupant est celui du navire équipé d'une hélice à pas fixe; lorsqu'il fait marche arrière, le sens de rotation de l'arbre porte-hélice est inversé. Durant ce processus, arrive un moment critique où l'arbre cesse sa rotation, mais où le navire peut continuer sa marche. Ainsi, si ce dernier, ou plus dangereusement encore, une pale de l'hélice heurte un gros fragment de glace, elle risque de se briser.

La recherche effectuée a consisté à prélever une pale de l'hélice en bronze renforcée, équipant le Canmar-Kigoriak, et à l'instrumenter en vue des chocs à lui faire subir. La série d'essais non destructifs effectués sur la pale a mis en évidence une fissure au pied de la pale. Par la suite, la pale a été projetée contre un bloc de glace d'eau douce, pendant que la chaîne de mesure enregistrait les forces, pressions et réactions en jeu. Certains essais ont été menés après que la pale eut connu une déformation permanente.

Aux fins de la recherche, un bâti de réaction complété d'un dispositif pour maintenir la pale d'hélice en place a été construit, conçu afin de résister à des forces de quelque 2,5 MN appliquées en bout de pale à une distance allant de 0,5 à 0,9 m, par rapport à l'axe central. Un actionneur à trois têtes, avançant à une vitesse relativement élevée, a appuyé un récipient contenant de la glace contre l'intrados de la pale. Les vitesses d'avance pratiquées entre 3 et 100 mm/s reproduisent celles d'une hélice à pas fixe lorsqu'elle heurte un gros fragment de glace. Tant les charges appliquées que les réactions du bâti ont été captées, grâce à un réseau de transducteurs, et transmises à une chaîne de mesure numérique qui les a enregistrées.

La charge appliquée par chacune des têtes de l'actionneur a été déterminée par le mesurage de la pression hydraulique exercée sur elles. Judicieusement placées sur l'intrados de la pale, des jauges extensométriques ont capté les déformations subies, qui sont proportionnelles aux contraintes exercées, tant que le matériau n'a pas subi de déformation plastique. Toutefois, comme l'un des objectifs de la recherche avait été de pousser l'essai au point de provoquer la déformation permanente de la pale, ces mêmes jauges ont servi à déterminer les pressions auxquelles s'amorce ce type de déformation. Le réseau de capteurs de déplacement a permis d'enregistrer les déformations, tant élastiques que plastiques, hors du plan de la pale. Un troisième réseau de capteurs dynamométriques a permis de mesurer les pressions d'interaction glace-pale à l'intérieur de la zone touchée. Les essais ont montré que, pour provoquer la déformation permanente de la pale, le facteur contraignant était moins la capacité de charge que l'amplitude du déplacement apporté par l'actionneur. Pour cette raison, du bois a été utilisé plutôt que de la glace dans deux des trois essais de choc. Enfin, deux essais de choc au marteau ont été faits en vue de déterminer les modes de vibration à l'état libre de la pale. Le tableau 1 donne les résultats obtenus des essais décrits.

TABLEAU 1

Résultats des essais de choc contre la glace

Essai no.	Glace		Form de la glace au contact	Surface (m2)	Vitesse (mm/s)	Charge max. (MN)	Point de contact	Observations	Déformation
	Type	Etat							
1	Bloc	Neuve	Rectang.	1.00	91.5	0.66	central	Deux pics de charge	élastique
2	Concassée	Neuve	Circulaire	1.54	85.7	0.53	central		élastique
3	Concassée	Usagée	Circulaire	1.20	83.3	0.53	central		élastique
4	Concassée	Usagée	Polygonale	0.68	100.0	1.03	central	Deux pics de charge	élastique
5	Concassée	Neuve	Triangulaire	0.60	100.0	0.37	central	Deux pics de charge	élastique
6	Concassée	Usagée	Polygonale	0.10	101.5	0.57	central		élastique
7	Concassée	Neuve	Circulaire	0.38	102.7	0.37	bord d'attaque	Deux pics de charge	élastique
8	Concassée	Neuve	Circulaire	0.68	100.0	0.53	bord d'attaque	Deux pics de charge	élastique
9	Concassée	Neuve	Circulaire	1.25	100.7	1.28	bord d'attaque	Deux pics de charge	plastique
10	Concassée	Usagée	Circulaire	0.91	102.9	0.42	bord d'attaque		élastique
11	Concassée	Usagée	Circulaire	0.91	100.7	1.13	bord d'attaque	Deux pics de charge	élastique
12	Concassée	Neuve	Circulaire	1.25	100.7	1.27	bord d'attaque		élastique
13	interrompu								
14	Concassée	Neuve	Circulaire	1.25	3.0	1.75	bord d'attaque	Ductile	plastique
15	Concassée	Usagée	Polygonale	0.60	5.5	3.93	bord d'attaque	Ductile	plastique
16	Essai vibratoire à l'état libre						bord de fuite		élastique
17	Essai vibratoire à l'état libre						central		élastique
18	Bois	Neuf		0.30	103.5	2.05	bord d'attaque		plastique
19	Bois	Usagé		0.30	102.7	2.40	récipient	Ruine	plastique

L'énorme quantité de données, une fois dépouillée, a révélé les détails intéressants suivants:

1. La partie centrale de la pale est plus chargée que ses bords. Il s'ensuit que les points de charge gravitent autour de l'axe longitudinal de la pale.

2. Les points de charge correspondent de près à ceux observés lors des essais en vraie grandeur.

3. La pression la plus forte observée a été de 28,20 MPa pour l'essai PBT15.

4. Les zones de tension observées sont de deux types: ductile et fragile.

5. L'essai PBT15 qui a produit la pression la plus forte a également produit la charge la plus élevée.

6. Il faut un déplacement de quelque 57 mm sur le bord d'attaque de la pale pour provoquer une déformation plastique.

7. Dans les essais de ductilité, 71 p. 100 de l'énergie mise en oeuvre a été consommée par la pale.

8. Lors des essais de fragilité, presque toute l'énergie mise en oeuvre a été consommée par l'écrasement de la glace et son extraction.

9. A partir d'une charge d'environ 1 MN, toutes les courbes contrainte-déformation cessent d'être linéaires.

10. Un écoulement plastique a été observé à la pression de 200 MPa.

Toutes les observations faites sur les interactions ainsi que la réponse de la pale aux sollicitations ont été revues et interprétées du point de vue de l'ingénieur. Cela a donné les constatations suivantes:

1. La pale de l'hélice à pas variable, protégée par une tuyère, s'est révélée être très robuste quant à la charge maximale qu'elle peut supporter jusqu'à la ruine totale, 3,95 MN, soit plus du double du 1,838 MN donné par les fabricants eux-mêmes.

2. A cette valeur de charge, la déformation résiduelle de la pale près du bord d'attaque a été considérable (40 mm) bien que localisée, et la pale reste quand même fonctionnelle, à condition de réduire le régime.

3. Malgré le nombre de cycles de charge, et leur amplitude élevée, aucune tendance à la fragilité n'a été observée. Ce qui veut dire que la fissure constatée au pied de la pale est probablement due à des cycles de charge de faible amplitude, des charges hydrodynamiques ou inertielles, par exemple, et non causée par les cycles de forte amplitude attribuables au contact direct avec la glace. La fissure se trouve du côté intrados de la pale.

4. La fonctionnalité de la pale ne dépend pas de sa robustesse (charge de rupture) mais bien de sa géométrie déformée sous charge et de l'influence que celle-ci a sur le rendement propulsif de l'hélice et les niveaux vibratoires. Le problème doit donc être envisagé sous l'angle de la raideur des sections de pale et non de leur résistance.

5. Plus de la moitié de l'énergie dépensée pour solliciter la pale est consommée par le processus de déformation plastique. Ce qui montre que la déformabilité plastique de la pale constitue un mécanisme de protection et qu'il devrait donc entrer en ligne de compte dans la modélisation de la réponse d'une pale aux charges élevées.

Recommandations:

1. Elaborer et utiliser un modèle de simulation des interactions glaces-pale d'hélice qui tienne compte des résultats obtenus.

2. Entreprendre la comparaison des données théoriques aux données pratiques, dans le but de mettre en évidence la cause des avaries aux hélices.

3. Lancer une étude et des expérimentations sur les divers matériaux entrant dans la fabrication des hélices en vue de déterminer les charges correspondant à la limite d'élasticité, à la charge maximale et à la rupture par fatigue et, ainsi, mettre en évidence les causes de la ruine des pales d'hélice.

4. Analyser les données sous le rapport de leur utilisation dans la réglementation d'application de la Loi sur la prévention de la pollution dans l'Arctique se rapportant à la question du rapport résistance/raideur de la pale d'hélice et aux critères de résistance à respecter.

TABLE OF CONTENTS

1.0 **INTRODUCTION** 1

1.1 Background 1
1.2 Project Objectives 3
1.3 Organization of Report 3

2.0 **TECHNICAL CONSIDERATIONS** 4

2.1 Overall Interaction Parameters 5
  2.1.1 Required Force 6
  2.1.2 Selection of Propeller Blade 6
  2.1.3 Required Ice Strength 7
  2.1.4 Required Impact Velocity 7

3.0 **TEST APPARATUS** 8

3.1 Propeller Blade 8
3.2 Frame Design and Construction 9
  3.2.1 Introduction 9
  3.2.2 Design Requirement 10
  3.2.3 Frame Design 11
  3.2.4 Main Girder 11
  3.2.5 Reaction Plate 12
  3.2.6 Connector 13

3.3 Ice Bucket 13
3.4 Hydraulic Actuators and Skid 14
3.5 Control of Actuators 15
3.6 Instrumentation 15
  3.6.1 Actuator Movement 15
  3.6.2 Applied Force 17
  3.6.3 Frame Design 18
  3.6.4 Blade Strain 18
  3.6.5 Blade Displacement 21
  3.6.6 Blade Surface Pressure 21
  3.6.7 Electronic Systems 27

3.7 Measurement Cycle 31
  3.7.1 Manufacture of Ice Block 31
  3.7.2 Mounting 44
  3.7.3 Testing 44

4.0 **PHOTOGRAPHS ILLUSTRATING THE PROJECT** 44

5.0 **CONCLUSIONS** 62

6.0 **RECOMMENDATIONS** 62

REFERENCES 63

APPENDIX A:

1. Machine Drawings
2. Non Destructive Testing on Propeller Blade
3. Overload Detector Schematic
4. Software Listing
5. Calibration Data on Blade Pressure Cells
6. Blade Test Data Plots
7. Fourier Transform of Blade Hammer Tests
8. Minimum and Maximum Values of Data Plots
9. Equipment Specifications

LIST OF FIGURES

1.1 Experimental Set Up
1.2 The Propeller Blade

3.1 Servo Control Electronics
3.2 Location of Strain Gauges on Frame Backstop
3.3 Location of Strain Gauges on Reaction Frame
3.4 Location of Strain Gauges on Block Tension Side
3.5 Location of Strain Gauges Blade Compression Side
3.6 Schematic of Blade Pressure Cell
3.7 Response of Blade Pressure Cells
3.8 Location of Sensors on Blade
3.9 Block Diagram of Electrical System
3.10 Transducer Designate Table
3.11 Ice Block PBT01
3.12 Ice Block PBT02
3.13 Ice Block PBT03
3.14 Ice Block PBT04
3.15 Ice Block PBT05
3.16 Ice Block PBT07
3.17 Ice Block PBT08
3.18 Ice Block PBT09
3.19 Ice Block PBT10
3.20 Ice Block PBT15
3.21 Location of Actuator Tests 1 to 6
3.22 Location of Actuator Tests 7 to 19

LIST OF TABLES

3.1 Principal Particulars of Propeller Blade 9

3.2 Maximum Load as a Function of Point of Application 12

1.0 INTRODUCTION

1.1 Background

Regulatory bodies, ship designers and ship operators are all concerned with a variety of damage to vessels. In many cases the damage may not lead to any serious consequences. For example, local plating damage may not require any immediate remedy. On the other hand, damage to the propulsion and steering system can often lead to a need for an immediate response and to serious consequences for the overall vessel safety. In ice going vessels, the predominant cause of propulsion system damage is caused by ice/propeller interaction. The interaction can lead to damage to the propeller blades, hub or shafting [1]. In particularly severe cases, all propeller blades can be broken [2]. Depending on the ice conditions, replacement or repair of the broken blade may not be possible. There have been cases of vessels becoming beset in ice for many months due to a damaged propulsion system [3].

There are many scenarios which can cause damage to propellers, a particularly severe case is the following: Consider a vessel which has a fixed pitch propeller. To reverse the direction of motion, of the vessel, the rotation of the propeller shafting has to be reversed. During this reversal a critical period occurs in which the shaft is stopped but when the vessel may still be moving. During this critical period, if the ship and more significantly the blade, contacts a massive piece of ice the blade may break. This scenario is not uncommon and the Canadian Coast Guard vessel Martha Black recently lost three blades during backing maneuvers in ice [4].

To understand the phenomena occurring during such a severe interaction there are a number of approaches:

- theoretical and numerical finite element calculations
- model scale tests
- full scale tests

The first approach is practical if the engineering properties of the ice and the blade are well understood plus a detailed knowledge of the interaction scenario is available. However, for the interaction under consideration the details are not known with any degree of certainty. To perform model scale test one needs a knowledge of the significant physical parameters in order to correctly scale the ice data. The full scale tests on the blade can be subdivided into two major types, tests using blades mounted on vessels and tests using full size propeller blades removed from vessels. Ice propeller interaction measurements using vessels are not available due mainly to the difficulties in conducting such tests. Firstly, the propeller blade would have to be suitably instrumented. Secondly, as one aim of the present investigation is to load the blade to failure then a distinct possibility exists of damaging or even breaking the blade. Furthermore as the tests would be conducted in heavy ice the safety of the vessel may be compromised. For these reasons the interaction tests of this project were conducted at full scale on blades removed from vessels.

In this project we took an ice strengthened bronze propeller blade which has seen service on Canmar's M.V. Kigoriak in the Canadian Beaufort Sea and suitably instrumented it. The blade was mounted on a custom designed load test frame. Subsequently the blade was rammed into hard fresh water ice and the forces, pressures and reactions were measured. Some tests were continued to the point where the blade was permanently deformed. In this manner valuable information was obtained which provided:

- Ice interaction pressure distributions across the blade face
- Pre-yield and post-yield behaviour of the blade
- Blade reaction in terms of deformation and strain
- Global ice forces during the interaction

The data so obtained is useful in:

- Providing full scale data to calibrate theoretical and numerical interaction models

- Giving insight into the phenomena occurring during such interactions
- The setting of regulations for propeller blade strength and stiffness

1.2 Project Objectives

The specific objectives of the project were:

- To experimentally measure the out-of-plane blade reaction when it is subject to ice forces and to record the applied loading.
- To determine the ice pressure-distribution in the contact area
- To record the blade strain during ice interaction
- To load the blade to the point where permanent blade deformation occurs
- To investigate the post yield behaviour of the blade
- To reduce the data to engineering units and perform initial analysis of the collected data
- To provide recommendations based on the data analysis

1.3 Organization of Report

The report has been divided into two volumes. Volume I describes the design and construction of the test apparatus along with the data obtained from the various blade tests. The analysis and interpretation of the collected data is provided in Volume II. While the project managers were GEOTECHnical resources ltd. Volume I was primarily the responsibility of GEOTECHnical resources ltd. whereas Volume II was primarily the responsibility of Arctic Research and Development. As is common in complex projects the various aspects of the project influence each other. GEOTECH had a significant input into the Data Analysis Report and specified its detailed terms of reference. ARAD had input into the Data Collection Report.

2.0 TECHNICAL CONSIDERATIONS

The project is concerned with the physical measurement of the interaction between propeller blades and ice. The particular interaction of interest occurs when the blade is not rotating and the interaction velocity is low (less than about 0.5 knots). In these interactions the blade is loaded such that the out-of-plane force is large and the in-plane component is small. The blade is much stronger in the in-plane direction than in the out-of-plane direction. The blade when it is not rotating is pushed "flat on" onto the ice sheet without any advantage of ice shearing and flaking that can occur when the blade is rotating.

In this project we shall be loading the blade so that the tip of the blade is in contact with the ice. The approach velocity between the ice and the blade was in the range of 3.0mm to 100mm/s.

For the interaction to occur one needs obviously, ice, a blade and a means to bring the two into contact. In any ice interaction study the first question is what type of ice? Here we are interested in interaction between propeller blades and hard ice. In this category are glacial ice and multi-year ice. The ice properties depend upon a large array of factors including, temperature, ice salinity, ice type, crystal size, size of interaction zone, speed of interaction, multiaxial stress state [6].

We are interested in using ice which is representative of the extreme ice types. In this case we principally have the choice of using glacial ices, multi-year ice or freshwater ice. When reviewing the mechanical properties of the extreme ice types, the variation in properties from sample to sample of any one type is comparable with the difference between ice types. Thus there is not a strong argument for these tests to use one ice type in preference to the other. There are however strong logistical and financial arguments in favour of using freshwater ice rather than glacier ice or multi-year ice.

In the field, the interaction between the blade and the ice can be considered to be semi-infinite in extent. This means that the dimension of the ice block should be larger than the physical dimension of the interaction. There are two options for the testing approach, the first is to test the blade on a freshwater lake, the second is to perform the tests in a laboratory situation. In the second alternative large blocks of ice in a restraining jacket would simulate the semi-infinite ice sheet.

The blade needs to be representative of those designed for ice service. Two major material types have been used in the Canadian Arctic, bronze alloys and stainless steel. While both bronze and stainless steel blades have approximately the same ultimate strength the yield point of the bronze alloys is much lower [7]. This results in the bronze blade potentially operating in the post-yield part of its response, a region in which comparatively little data is available. Much experimental, theoretical and field work has been conducted by and for the Canadian Government on bronze blades [8, 9, 10].

The means to bring the blade and ice into contact are many, for example: gravitational impact, screw driven mechanisms or hydraulic actuators. Gravitational impact can provide high velocities, but control of the impact is poor and the energy available low. Screw driven mechanisms are mechanically complex. Hydraulic systems have a proven history and can provide the energy and velocity requirements. The hydraulic system was selected.

2.1 Overall Interaction Parameters

In the following subsections we estimate the magnitude of the critical parameters required to conduct the tests.

2.1.1 Required Force

According to the manufacture of the M.V. Kigoriak blade (LIPS), approximately 1200 kN at relative radius 0.9 and near the leading edge is required to produce yield.

The blade material yield stress is approximately 250 MPa and ultimate 650 MPa [10]. We are interested in the post-yield behaviour as well as the pre-yield behaviour. Thus for the experiment we shall design for a maximum applied force of 2500 kN.

2.1.2 Selection of Propeller Blade

There are a wide variety of blade shapes in current operation. For ice use there are two main variants, shrouded and open. We shall outline the relevant differences between the two types.

There are differences between the blade contour and the material distribution, the principal difference being large corners on the shrouded blades (Kaplan type). The stress and strain distribution near the blade tip will be significantly different for the two blade types. However, near the root of the blade where most failures occur, the two blade types are very similar.

One output of the project is to calibrate the response of a particular blade to a particular loading condition. Thus once a theoretical model has been calibrated using full scale data one should be able to run the model for other similar blade shapes. Lastly one additional output of the project is to investigate the response of the blade to different areas of loading. This will be accomplished by adjusting the contact area rather than by adjusting the blade contour.

In conclusion there are not particularly strong arguments in favour of one ice strengthened blade over another. The important aspect is to test a blade designed for ice service.

2.1.3 Required Ice Strength

The estimated maximum contact area between the M.V. Kigoriak blade and the ice is $1.2 m^2$. To attain the maximum design load of 2500 kN requires an interaction pressure of 2.1 MPa. Based on data from ship-ice interaction studies [12], the required pressure is attainable with ice.

One particularly relevant set of data was obtained in work performed by GEOTECH [13]. In these experiments rectangular or triangular flatjacks were vertically mounted adjacent to the ice surface. The time history of the pressure was recorded under a number of conditions. The geometrical size of the flatjacks was comparable to the size of the propeller blade in this test program. In these tests, flatjack deformation rates of up to 40mm/s were attained.

2.1.4 Required Impact Velocity

For the vessels manoeuvring in ice, the typical normal velocity would be in the rage of 0 to 500mm/s (approx 0 to 1 knot).

A common way of characterizing ice interaction is by the use of strain rate. This has an unambiguous fixed value for finite size uniaxial tests. For indentor tests or semi-infinite ice the strain rate will vary from a maximum near the interaction zone to zero, remote from the interaction zone. Thus an effective strain rate has been introduced by many workers. One such value can be expressed as [6]. $\dot{\varepsilon} = v/4b$

where: v = velocity of approach
b = width of the contact zone

Data produced by Michel [6] indicate that below a strain rate of approximately $5 \times 10^{-4}\ s^{-1}$ the ice acts in a ductile manner, above approximately $5 \times 10^{-3}\ s^{-1}$ it behaves brittly and between these two is the so called transition zone. Combining these limits with the above equation and characteristic dimensions of the contact zone implies that at velocities greater than about 10mm/s the ice will fail brittly. It is thus expected that for the case of propellers on vessels the ice will be failing brittly. Hence for the current tests the actuator system should be capable of providing an approach velocity greater than about 10mm/s.

3.0 TEST APPARATUS

The overall testing apparatus is illustrated in the pictures showing the development of the project, see Section 4.0. The major components shown are, the triple actuator skid, the reaction frame, the propeller blade mounted on the reaction frame and the ice bucket.

In operation, the forward motion of each of the three actuators is controlled via a hydraulic servo system. The ice held within the ice bucket is thereby forced into the propeller blade. The overall interaction force is recorded by means of the hydraulic oil pressure in the actuators. The blade reaction was monitored by a combination of foil strain gauges mounted on the blade surface and displacement potentiometers recording the out-of-plane displacement of the blade. The details of the ice/blade interaction was monitored by a series of custom designed pressure cells mounted flush with the blade surface.

For the sts program, the majority of the tests were at a nominal interaction speed of 100mm/s. Tests were also conducted at 3mm/s and hammer impulse tests were conducted to record the natural modes of the blade vibration.

3.1 Propeller Blade

The propeller blade was acquired from Canadian Marine Drilling, Calgary, Alberta. The blade had seen service on the M.V. Kigoriak and was considered to be unserviceable due to its length of service. The principal particulars of the blade and its nominal material properties are given in Table 3.1. Further details are provided in Volume II.

The owners considered the blade to be of scrap value only. At their yard in Nisku, Alberta were eight (8) blades from the M.V. Kigoriak. A team member made a visual inspection of the propeller blades and selected one blade that had no obvious signs of severe damage. Some of the blades had sections of the leading edge of the blade missing. The blade was then transported to GEOTECH in Calgary. Upon receipt of the blade it was subjected to a set of non-destructive tests consisting of dye penetrant and ultrasonic inspection.

The results of the non-destructive testing are detailed in Appendix A.2. The principal finding of which was the presence of a crack system in the blade root. Communication with Canmar personnel [14] indicated that they were unaware of the presence of the crack and it was not removed from service because of that crack. The blade was otherwise free from major defects.

The occurrence of the crack had the consequence that for the testing of the blade the crack must be on the compressive side of the blade otherwise blade failure may be instigated by crack propagation from the defect.

Table 3.1

Principal Particulars of Propeller Blade

o	Manufacturer	LIPPS	Drunen, Holland
o	Material	Cunial Bronze	
o	Designation	CPP	
o	Size	tip to foot	1670 mm
o	Weight	2700 kg	
o	Material	Yield strength	640 MPa
		Ultimate strength	270 MPa
		Elongation	20%

3.2 Frame Design and Construction

3.2.1 Introduction

In November, 1987, GEOTECHnical resources ltd. were awarded a contract to test a controllable pitch propeller to the point of failure. The load was to be applied with a series of three hydraulic rams applied through a block of ice onto the face of the block. The actuators and other hydraulic equipment necessary to do this were already in the possession of GEOTECH. Mr. M.W. Smyth, P.Eng. was contacted by GEOTECH to perform a detailed design of a reaction frame. The general terms of reference for the frame were set by GEOTECH. We describe the design considerations and details that entered into the design process, and a summary of the load carrying capabilities of the frame. The machine drawings of the frame are presented in Appendix A.1.

3.2.2 Design Requirements

The main requirements of the frame was to react against the load applied to the block by the actuators, and to transfer the load back to the connection point of the block to the frame. Other requirements and considerations included:

- The maximum load exerted be each actuator was approximately 5 MN
- Maximum stroke of each actuator was .25m.
- A clear space of 2.7m was required for the actuators, ice block and the allocated ice containment vessel.
- The actuator skid was required to be moveable such that the reaction from each reactor could be located anywhere within a rectangle .75m high and .5m wide.
- The blade connection detail must be such that the blade will not rotate or slide during the test, yet must allow the blade to easily be rotated in small increments to allow the proper orientation of the blade with respect to the ice block.
- The bending moment required for first yield at the base of the block is estimated to be 1.5 MN.m. A bending movement of 6.4 MN.m is estimated to be required to development a plastic hinge at the base of the blade.

- Due to economic constraints the load factor was taken as 1.0. A material factor of .9 was used in the design.

- The load is applied rather quickly, with the maximum actuator speed being 100 mm/sec. Therefore, there may be some dynamic magnification of the load, depending on the nature of the failure of the ice. Although it was recognized as something to consider, the dynamic magnification factor for design was taken as 1.0.

- In light of the use of a load factor and dynamic magnification factor of 1.0, several strain gauges were placed on the frame to monitor its integrity during testing.

- The strength of the frame should be that the blade fails first.

- A high stiffness design is preferable.

3.2.3 Frame Design

The frame was designed using the principles of plastic steel design as discussed in the CISC Handbook of Steel Construction. The only exceptions to the handbook procedures are the use of a load factor of 1.0, as opposed to 1.5, and no dynamic magnification factor, although naturally the handbook does not cover any similar cases.

The construction drawings of the frame are given in Appendix A.1. The design of each component is discussed in turn.

3.2.4 Main Girder

The main girder is designed as a plastic beam/tension member. The load may be applied at a point directly above the longitudinal axis of the beam, or may be offset by up to .5m from this axis. In the latter case the design condition is biaxial bending with an axial tensile force. The former case is simpler, being uniaxial bending combined with an axial tensile force. In both cases the same philosophy as used for beam columns was adopted. A rectangle stress block about an assumed neutral axis is used to calculate the resistance of the section to the applied loads. The section adopted is a box girder with overall depth of 1.25 m and width of .65 m. The top flange is 1.0 m wide and an additional flange is added midway between the top and bottom flange. All material is .025m thick. This additional flange is added mainly to reduce the height of the web panels, buckling being the likely mode of failure. The resulting width to thickness ratio is 24, which means the plate will carry about 93% of its yield stress before buckling. Recall that a material factor of .9 is used, which means we are on the conservative side. The plastic moment capacity of the girder is such that it can carry the loads applied to the blade indicated in Table 3.2. These loads are unfactored.

Horizontal Position	Vertical Position	Maximum Load (MN)
Centre line	0.9 relative radius	5.1
Centre line	0.7 relative radius	7.0
0.5 m off Centre line	0.9 relative radius	2.6
0.5 m off Centre line	0.7 relative radius	4.0

Table 3.2: Maximum Load as a Function of Point of Application

3.2.5 Reaction Plate

The front face of the reaction plate is designed to resist the reaction of the actuators at every possible load application point. Recall that the actuators are allowed to move within a .75 m x .5 m rectangle. Stiffeners under a thin plate are governed by shear capacity. The overall Reaction plate is governed by a contraction of shear, bending and tension at the point where it connects to the girder. Its capacity is the same as the main girder.

3.2.6 Connector

The method of connection of the blade to the main girder was given much consideration. The primary function in the design was to minimize the cost of machining large pieces of steel. It was necessary to keep the size of the pieces requiring machining as small as possible. The solution adopted involves bolting the blade to a 100 mm plate 1 m in diameter. This plate is in turn clamped to the structure. The bending moment is resisted by bolts and clamps on the tension side, and direct bearing on the girder support structure on the compression side. Shear is resisted by reaction on a bearing strip welded to the top of the girder. Torsion is resisted by friction developed in the connection.

3.3 Ice Bucket

The ice bucket utilized a spare part left over from a previous set of tests. It functions as a containment vessel for the ice and as a reaction plate to transfer the load to the three actuators. The ice bucket performs two functions, the first is to hold the ice in place prior to contact between the ice and the blade. The second function was to provide a measure of restraining force to the ice in order to simulate a semi-infinite ice sheet. During the initial design phase of the project, some thought was given to the mechanical arrangement for such lateral support of the ice block. The principal difficulty was in providing a system stiff enough to provide the support yet flexible enough in the longitudinal direction so that the support/blade contact load would be small compared with the ice/blade contact load.

To estimate the thickness of the restraining ring which would provide the same radial deflection as provided by a semi-infinite ice sheet we use the following equation [16].

$$t = \frac{b}{(1+\nu)} \cdot \genfrac{}{}{0pt}{}{E_{ice}}{t_{ring}}$$

where:
t = thickness of ring
b = internal radius of ring
ν = 0.3
E_{ice} = Youngs modulus of Ice
E_{ring} = Youngs modulus of Steel

Using the following values:

$b = 0.7$ m
$E_{ice} = 5 \times 10^{9}$ Pa
$E_{ring} = 2.1 \times 10^{11}$ Pa

the thickness of the retaining ring is 12.8 mm.

This thickness of metal would likely dominate the blade/bucket interaction force over that of the blade/ice force. It was decided to then, use a partial length of restraint, the main purpose of which was to hold the ice in place during assembly of ice block. The ice block would protrude out of the ice bucket unsupported.

3.4 Hydraulic Actuators and Skid

The hydraulic actuator skid was built and developed by GEOTECH which GEOTECH performed for a joint industry field project [5]. The hydraulic actuators have double acting pistons to allow for precise motion control. The main characteristics of the hydraulic system are

o	Maximum working pressure	35 MPa
o	Maximum thrust per actuator	4.5 MN
o	Servo valve flow rate	200 USGPM
o	Actuator slew rate at maximum working pressure	170 mm/s

A significant constraint was that the whole skid was designed for compressive loads and not tensile loads. This has the consequence that the effective point of load application must be within the triangle formed by the three actuators. If the effective point of load application is outside of that triangle then one or more of the actuators will have to provide a tensile load.

A comparison of the size of the critical triangle with the size of the blade indicated that to load different areas of the blade the whole actuator skid needed to be movable.

3.5 Control of Actuators

Each actuator is under displacement feedback in order to attain a prescribed velocity. The net load supplied by each actuator is not a controlled variable, but is determined by the condition of the prescribed displacement. Each actuator however, is driven by the same command signal to ensure coincident progression of the three actuators. The schematic for the electronic servo control system in shown in Figure 3.1. A series of tests were conducted to ensure that the forward and reverse motion of actuator was identical.

The diameter of the ice bucket is larger than the triangle formed by the three actuators. This has the consequence that the point of application of the load could be such that tensile loads are required. To prevent this occurrence, an electronic circuit was designed and constructed. The function of the circuit was to cause a retraction of the actuators if any of the actuators apply a tensile load. An additional condition for causing retraction of the actuators is that the total applied load is greater than a set overload level.

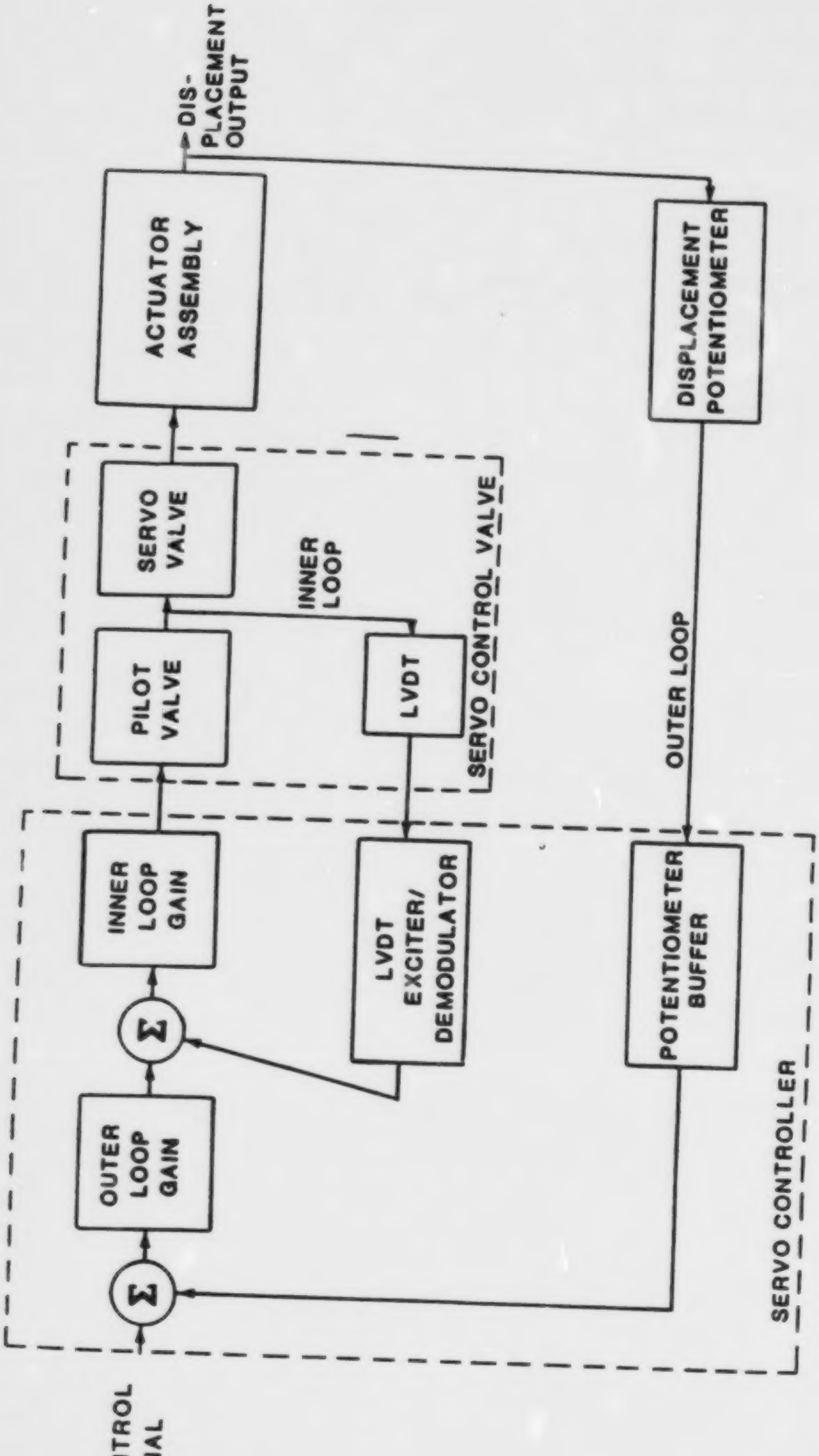
We thus have a means for controlling the forward motion of the actuators and a means of safeguarding the apparatus from two types of overload. The overload circuit schematic is shown in Appendix A.3.

3.6 Instrumentation

To record the applied loading of the blade and its subsequent reaction a series of transducer systems were attached to the test apparatus. These are described below.

3.6.1. Actuator Movement

Each actuator movement was monitored via a wireline extension gauge. The gauge monitored the movement of the piston attachment of the ice bucket relative to the cylinder of the piston. The specifications for these gauges is given in the Appendix A.9. This particular gauge was chosen based mainly on its successful


CONTROL SIGNAL
Σ
OUTER LOOP GAIN
Σ
INNER LOOP GAIN
LVDT EXCITER/ DEMODULATOR
POTENTIOMETER BUFFER
SERVO CONTROLLER
PILOT VALVE
LVDT
SERVO CONTROL VALVE
INNER LOOP
SERVO VALVE
OUTER LOOP
ACTUATOR ASSEMBLY
DISPLACEMENT POTENTIOMETER
DIS- PLACEMENT OUTPUT

SERVO CONTROL SYSTEM

GEOTECH

Figure 3.1

field use in previous test programs [5] and that the servo controller electronics were designed to accommodate this type of actuator.

3.6.2 Applied Force

The force exerted by each actuator is estimated by recording the oil pressure on both sides of the actuator piston. A knowledge of the area of each side of the piston will then provide the gross force applied. Three factors should be acknowledged however as causing potential errors.

1. Friction in the actuator pistons
2. Acceleration of the mass forward of the piston
3. Hydraulic transient effects

The first aspect of friction is addressed by measuring the load relative to when the piston is moving forward but before any ice/blade contact. The second aspect of acceleration can be estimated by viewing typical load time servo when piston movement just starts. Furthermore this magnitude of the effect can be estimated from the displacement time data collected during the test. The last aspect of hydraulic transient refers to turbulent motion of the fluid within the actuator resulting in the pressure at the transducer location not necessarily being the average pressure over the effective area of the piston.

An inspection of this data indicates that the largest of the three is the friction in the pistons, an effect however that was readily corrected for.

During the design stage of the project the possibility of inserting load cells between the pistons and the ice bucket were considered. While these devices, in principal would provide a direct measure of the applied loading, experience in previous field trials [5] indicated significant problems with off centre loading of these devices.

3.6.3 Frame Strain

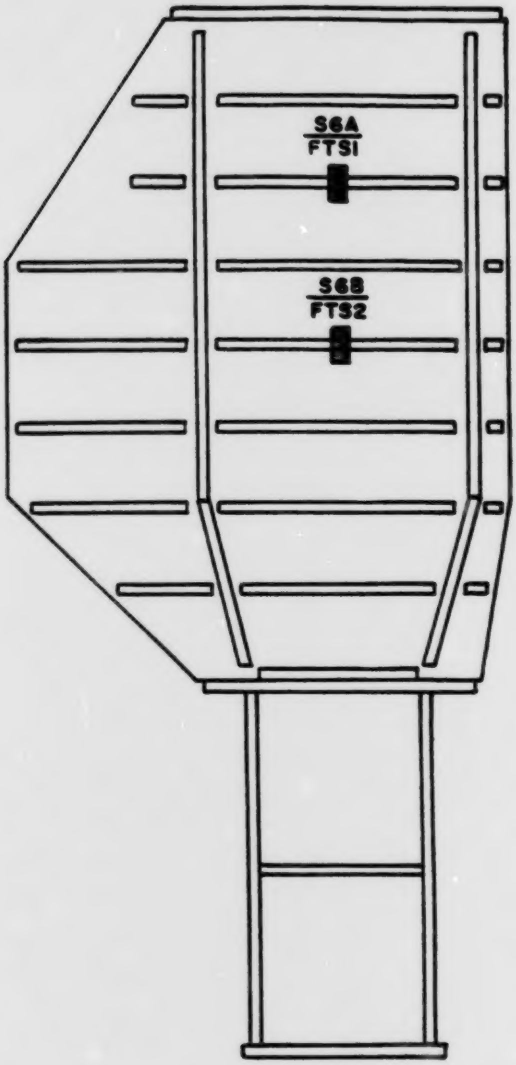
Due to the design of the reaction frame not using normal factors of safety in its design, see Section 3.2. a series of strain gauges were applied to the frame at highly stressed locations. The purpose of these gauges was not to provide a means of recording the loading but rather as a means of determining the structural integrity of the loading frame. The location of these gauges are indicated in Figures 3.2 and 3.3. Only a few locations were strain gauged in order not to significantly increase the number of channels of data to be recorded during the tests.

The strain gauges were Micromeasurements Number CEA-09-500UW-350 bondable gauges. Application followed normal manufacturers recommended practice. As the required life of these gauges was only about one month after installation and they were to operate in a relatively clean environment not much effort was expended in mechanical protection or sealing of these gauges. The gauges on the frame and on the propeller blade (Section 3.6.4) were installed by Hoogensen Metallurgical Ltd.

3.6.4 Blade Strain

A series strain gauges were applied to the propeller blade surface. Two types were installed uniaxial gauges and the 90' rosettes. The location of the gauges are indicated in Figures 3.4 and 3.5. Refer to Figure 3.10 for further explanation of symbols. Micromeasurements Number CEA-09-500UW-350 and CEA-09-250UR-350 were used and normal manufacturers recommended practise were used during installation. The majority of the gauges were on the compression side of the propeller blade with a smaller number in the blade root area on the blade tension side. The gauges were placed on the compression side so that the ice/blade impact would not destroy the gauges during each test. To provide for adequate protection of the gauges and their associated wiring would have been costly and furthermore would have significantly modified the stress distribution in the vicinity of the gauges.

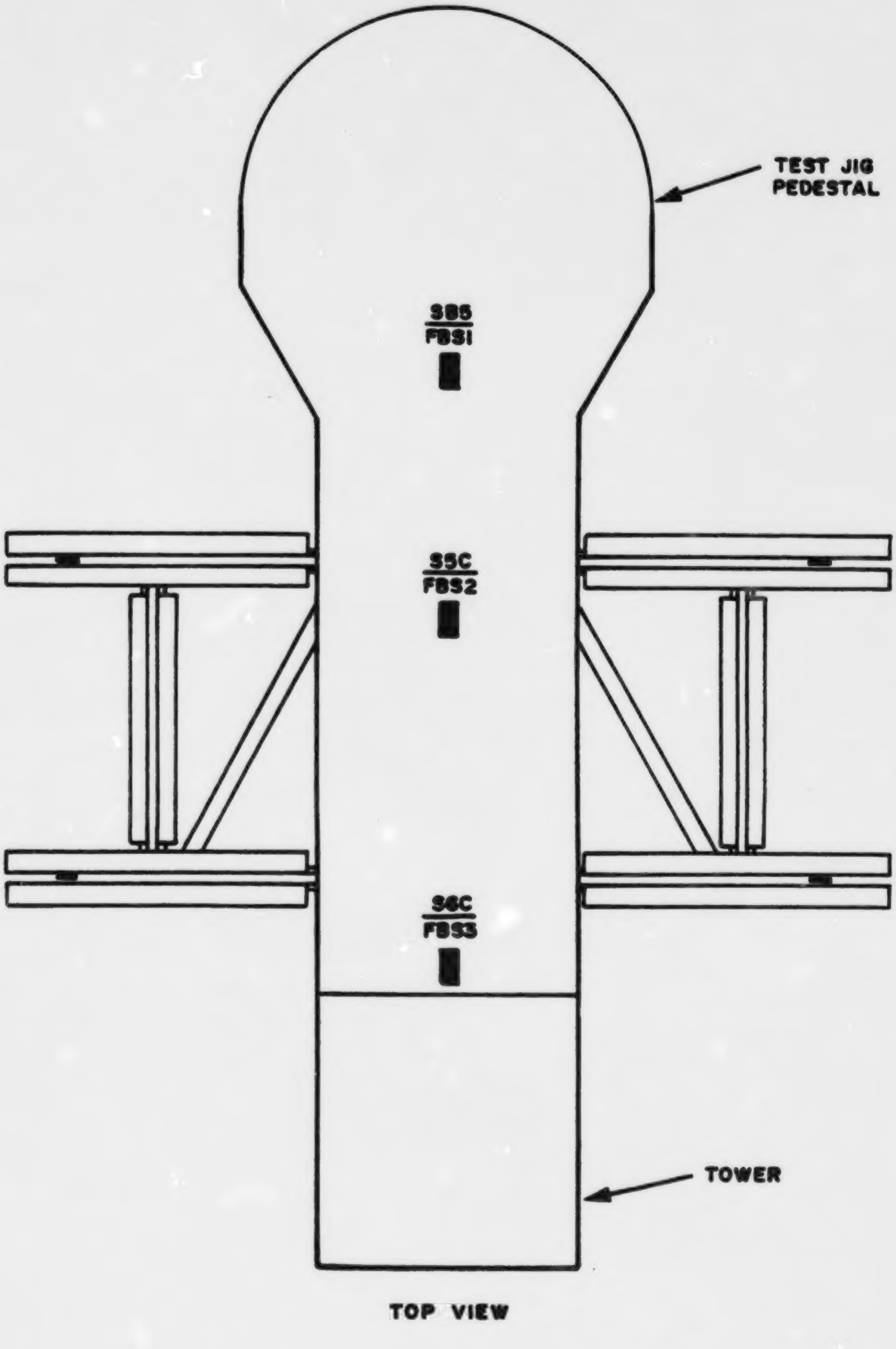
FTS - TEST FRAME TOWER (Backstop) STRAIN GAUGE
23 APR.'88


S6A
FTS1
S6B
FTS2

LOCATION OF STRAIN GAUGES
ON FRAME BACKSTOP

Figure 3.2

FBS - TEST FRAME BASE STRAIN GAUGE 23 APR. '88


TEST JIG
PEDESTAL
SB5
FBS1
S5C
FBS2
S6C
FBS3
TOWER
TOP VIEW

LOCATION OF STRAIN GAUGE
ON REACTION FRAME

Figure 3.3

3.6.5 Blade Displacement

One of the aims of the project was to produce plastic deformation in the blade. Strain gauges have limited ability in determining blade displacements and furthermore once the material has exceeded the yield point, then the full stress strain behaviour of the material would be required. A set of three displacement gauges identical to those used in the measurement of piston movement were used. These particular units have adequate resolution and have the distinct advantage over LVDT's in that they still continue to function in the presence of significant misalignment. This aspect is of particular importance given that the actual displacement and distortion of the blade is not under control. The transducers record the deformation of the blade in the direction of motion of the actuators. Sensor locations are illustrated in Figures 3.4 and 3.5. The deformation is relative to the blade foot so that the blade deformation measurements would not be contaminated by deformation within the reaction frame caused by the loading.

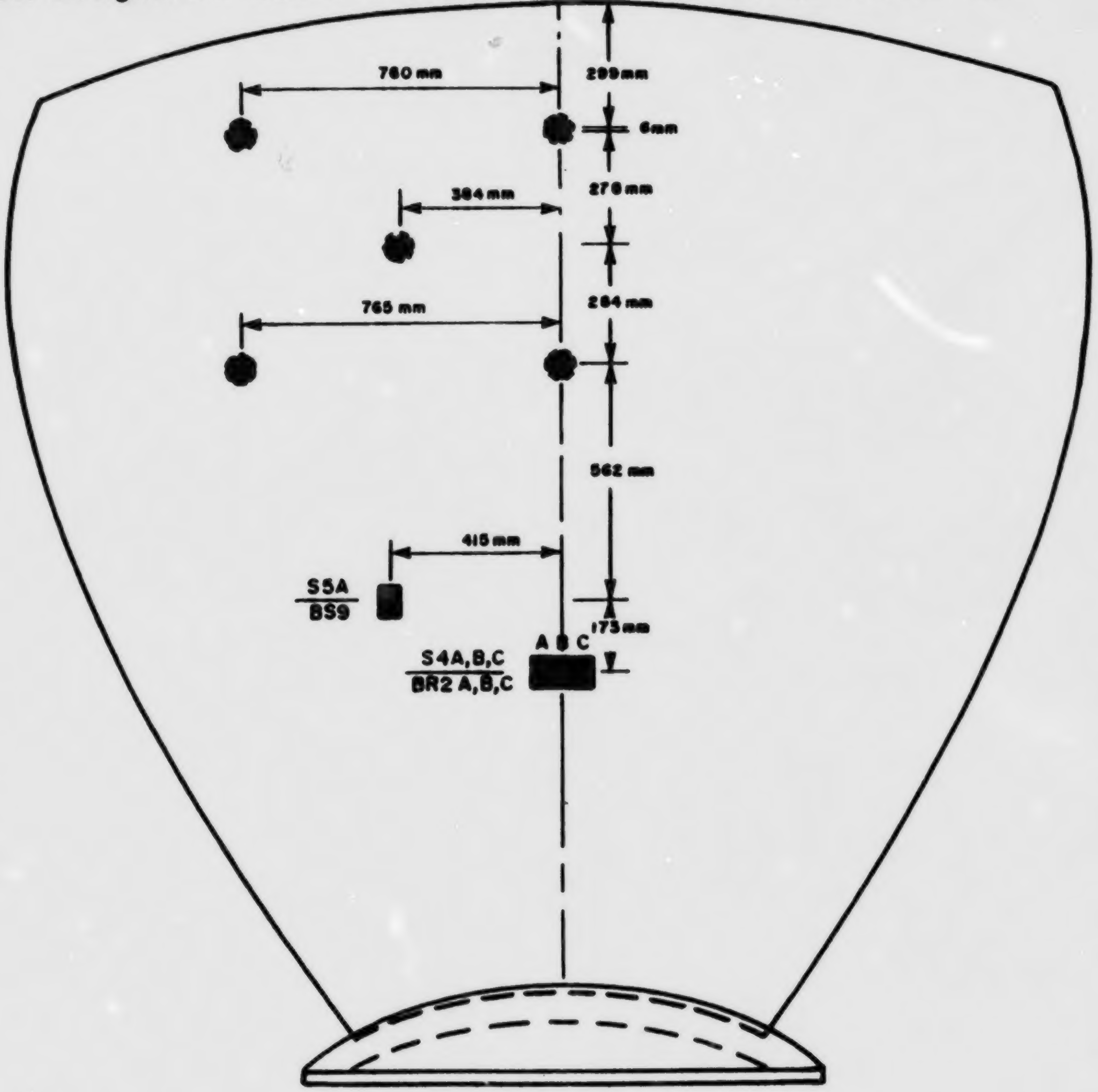
3.6.6 Blade Surface Pressure

To characterize the blade/ice contact more fully five especially designed pressure cells were mounted within the blade surface. These units are hydraulic devices which comprise a membrane, a hermetically sealed cavity, a fluid and an electronic pressure transducer. The choice of transducer resulted from a review of available types in light of the following requirements.

- Range to 50 MPa
- Sensor diameter; approximately 100mm
- Thickness; less than about 5mm
- Frequency response greater than 1 KHz.

The most stringent requirement was the thickness. Its necessity was to have the sensor surface essentially flush with the blade surface and yet not greatly altering the local blade stiffness. Sensors based on strain gauges are available with the appropriate diameter but not with the appropriate thickness.

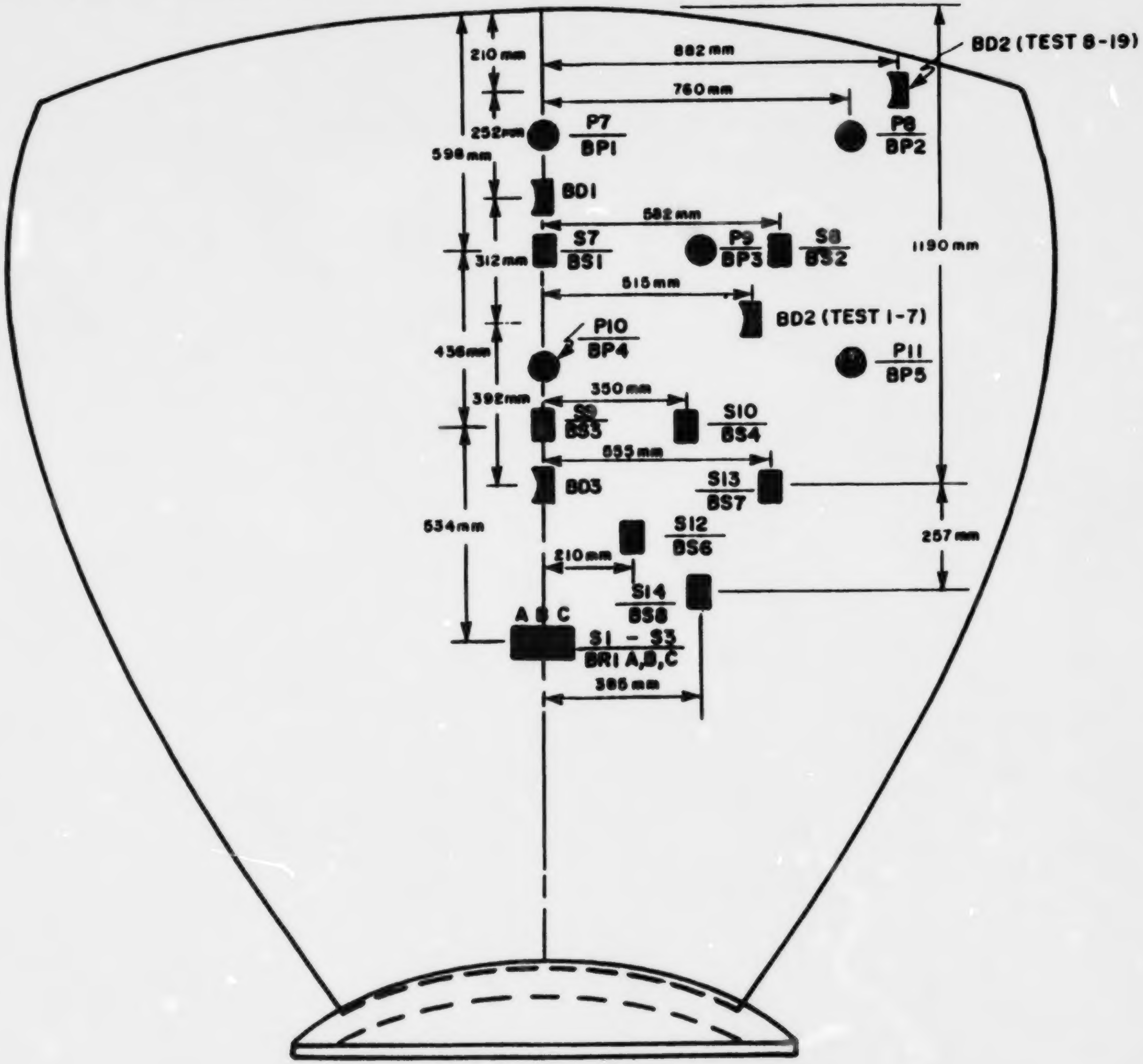
Sensor Designation: BLADE FRONT (TENSION SIDE) 23 APRIL '88


760 mm
299mm
6mm
384 mm
276 mm
765 mm
284 mm
562 mm
415 mm
173 mm
S5A
BS9
A B C
S4A,B,C
BR2 A,B,C

LOCATION OF STRAIN GAUGES
ON BLADE TENSION SIDE

Figure 3.4

Sensor Designation: BACK BLADE (COMPRESSION SIDE) 23 APRIL '88


BD2 (TEST 8-19)
210 mm
882 mm
760 mm
252 mm
P7/BP1
P8/BP2
598 mm
BD1
582 mm
S7/BS1
312 mm
P9/BP3
S8/BS2
1190 mm
515 mm
BD2 (TEST 1-7)
P10/BP4
436 mm
P11/BP5
392 mm
350 mm
S9/BS3
S10/BS4
555 mm
BD3
S13/BS7
534 mm
S12/BS6
257 mm
210 mm
S14/BS8
A B C
S1 - S3/BR1 A,B,C
386 mm

LOCATION OF STRAIN GAUGES
ON BLADE COMPRESSION SIDE

Figure 3.5

The overall design of this type of fluid filled sensor is described in detail in ref [15]. The sensor is shown schematically in Figure 3.6 and 3.7. In the current application we assumed that uneven loading of the sensor surface would occur. This had the consequence that to avoid local membrane yielding a thicker membrane would be required. To compensate for the increased membrane stiffness mercury rather than hydraulic oil was selected as the working fluid.

The actual construction of the sensors went through a number of stages in order to arrive at the final working device.

Version 1: The propeller blade was machined and a brass membrane would be silver soldered into the machined recess. Difficulties were encountered with the silver soldering of the two pieces.

Version 2: A hermetically sealed unit would be manufactured from brass which would fit into the machined recess. The silver soldering proved to be adequate but the material from which the units were made was found to be porous.

Version 3: As Version 2 except that the sealed unit was manufactured from stainless steel. T.I.G. welding was used instead of silver soldering. The unit was glued into the machined recess using a metal epoxy.

After mounting on the blade the electronic sensors was connected and the unit filled with mercury under vacuum. A vacuum pressure of about 50 microns was achieved during the filling process.

The theoretical response of the sensor to applied loads is given in Appendix A.5. The calculation is based on ref [15]. The slight non-linearity in response at low applied pressures is due to the small amount of residual air in the mercury fill.

The sensors were also tested in a load test frame at GEOTECH's facilities.

GEOTECH

4500 - 5th Street N.E., Calgary, Alberta T2E 7C3
Telephone (403) 230-4128

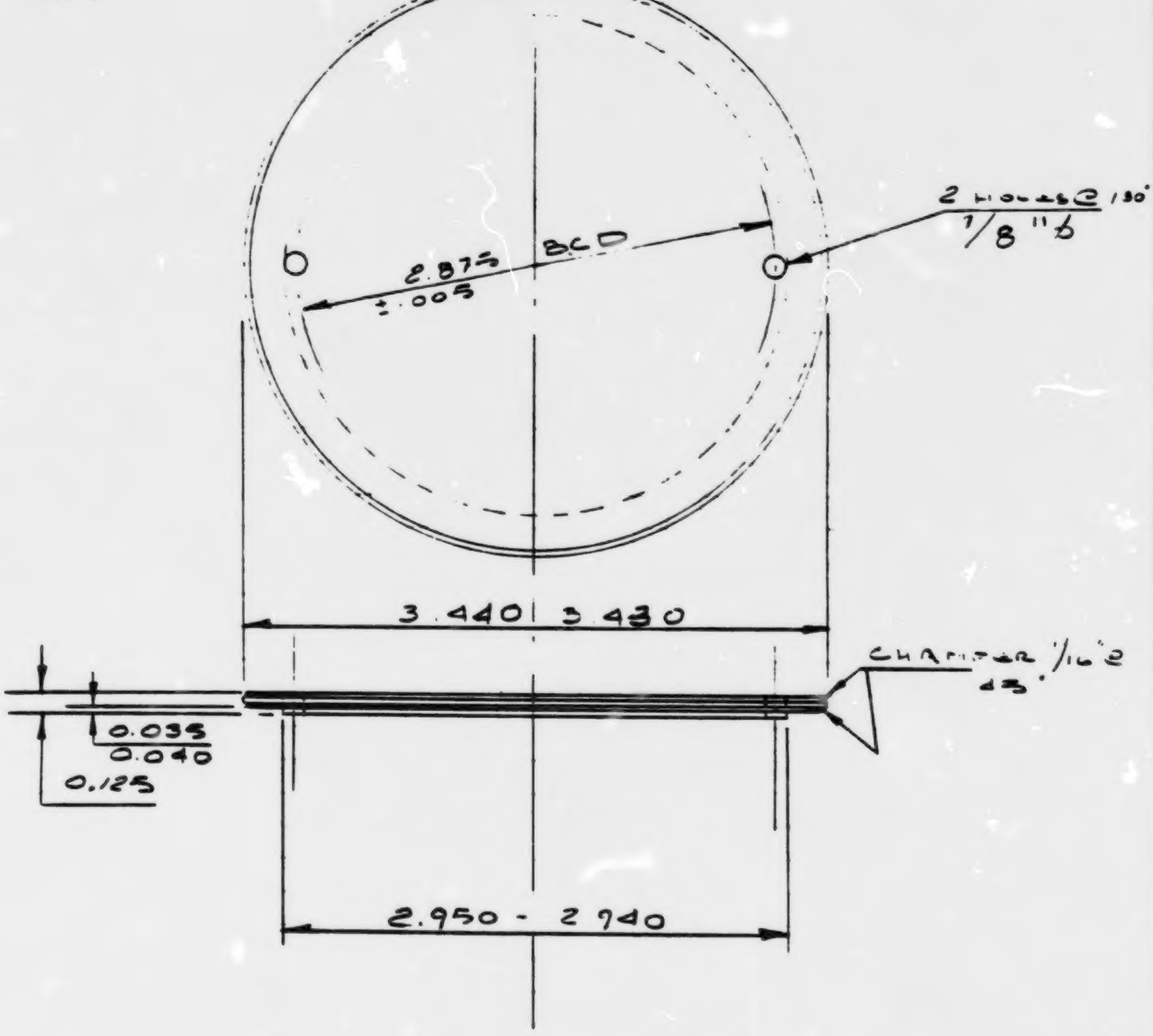
Project No	9848	Page	of
Company		Date	12 - April 1982

Subject Peep Buster - Pressure Cells

Prepared By B. Graham

5MM X 5MM 19 CM X 24 CM

6 Pieces



BCD
2.875
±.005
2 holes @ 180°
1/8" ⌀
3.440 3.430
Chamfer 1/16" @ 45°
0.035
0.040
0.125
2.950 - 2.940

Plate - Bottom
Full Size

Material - 304 SS

Figure 3.6a

GEOTECH

4500 - 5th Street N.E., Calgary, Alberta T2E 7C3
Telephone (403) 230-4128

Project No 7849
Page of
Company
Date 12 Apr - 1988

Subject Prop Buster

Prepared By B [illegible]

5MM X 5MM 19 CM X 24 CM

6-Pieces

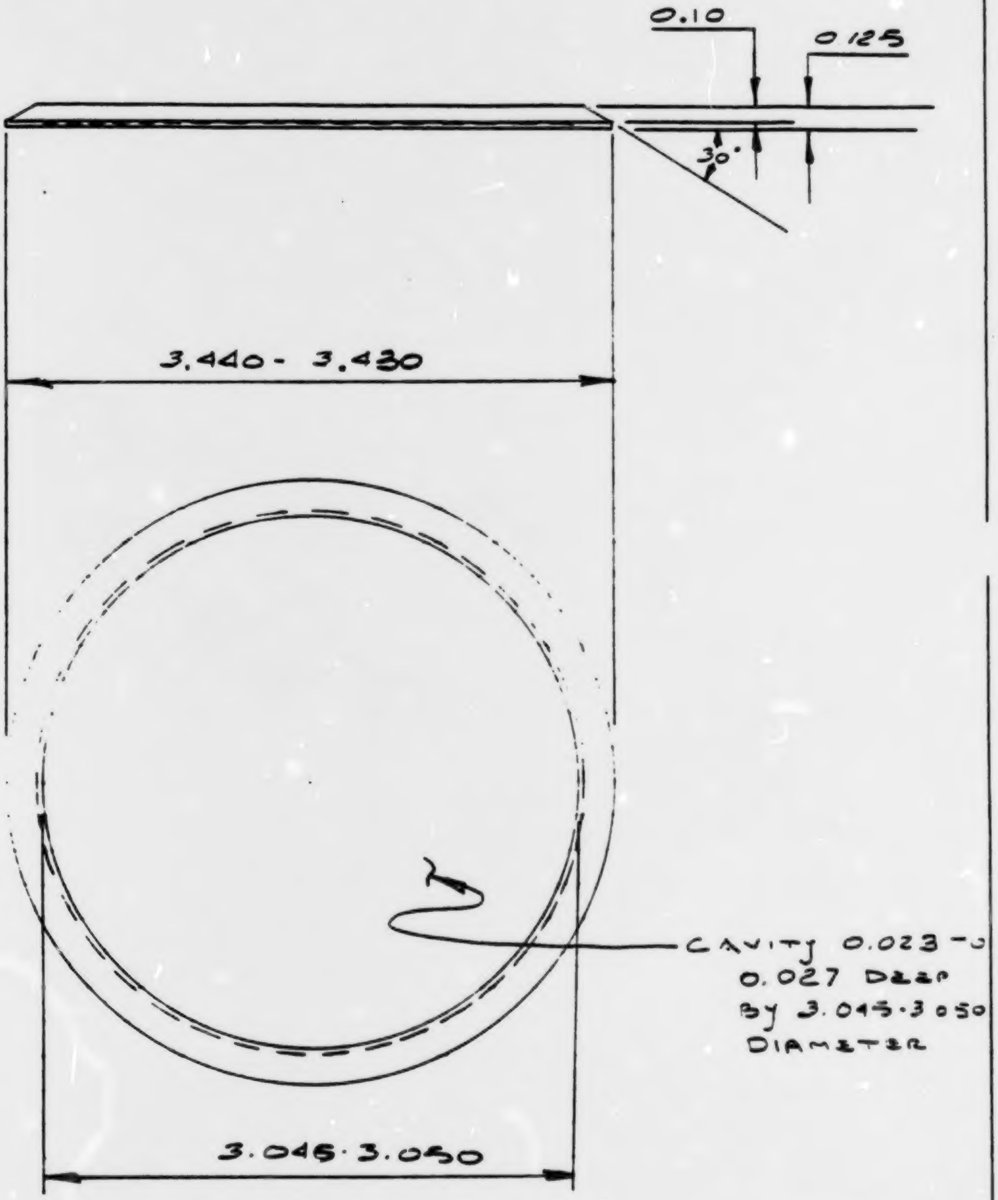

0.10
0.125
30°
3.440 - 3.430
CAVITY 0.023 - 0
0.027 DEEP
BY 3.045-3.050
DIAMETER
3.045·3.050

Figure 3.6b

The location of the gauges on the blade are shown in Figure 3.8. Refer to Figure 3.10 for further explanation of symbols.

3.6.7 Electronic Systems

There were some parts of the electronic system that were built for a previous project [5] and some parts of the system were specifically built for this project. A block diagram of the electronics is shown in Figure 3.9. The transducer designation table are given in Figure 3.10. The major elements designed for this project are the overload detector and the computer software.

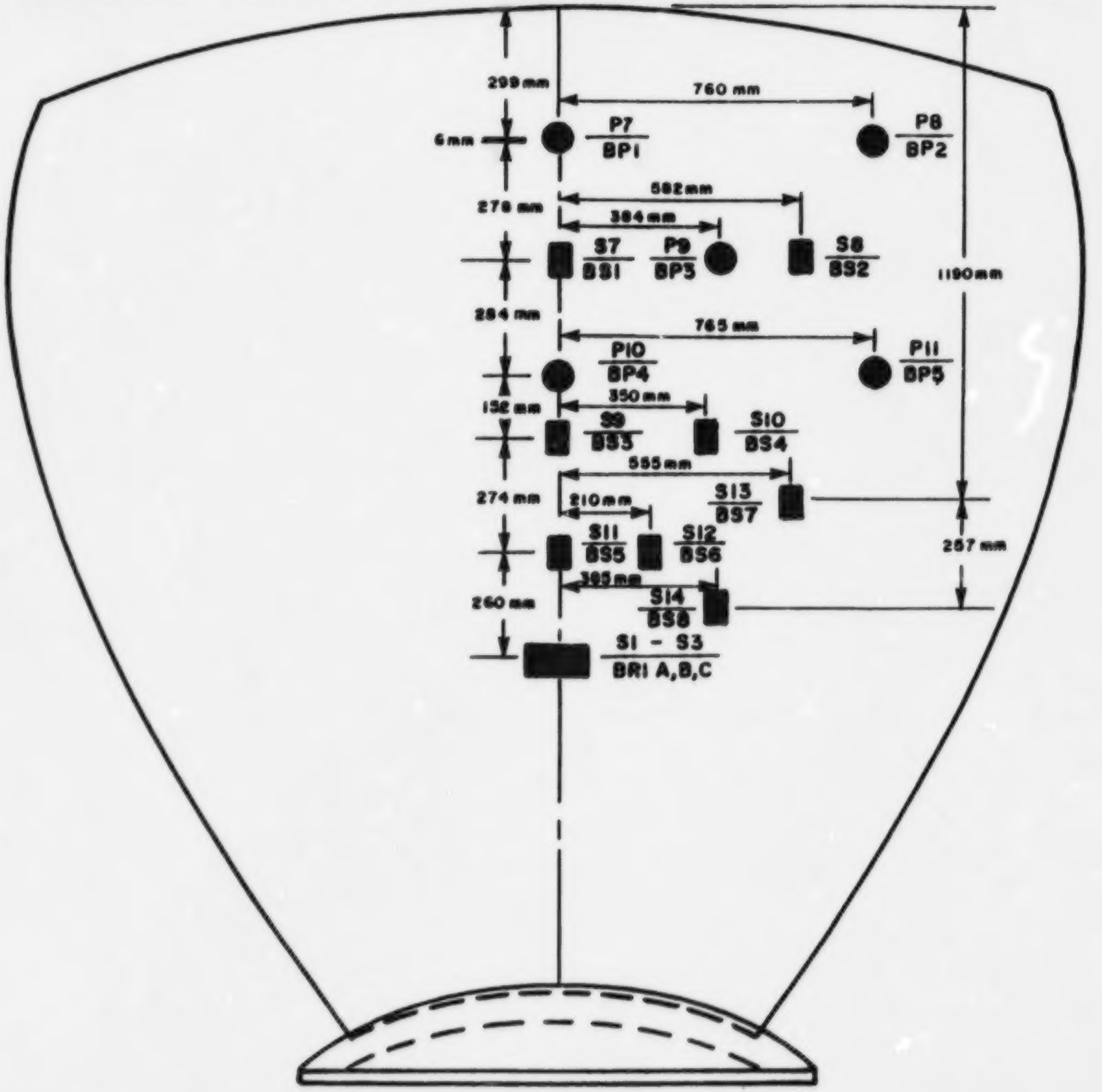
The overall specifications of the electronic data acquisition system are:

- 32 channels of data
- Maximum sampling rate per channel 5 kHz
- 12 bit resolution of the A/D converter
- Input range +/- 5.0 V
- Maximum number of readings per channel 32,000

The overall functioning of the system illustrated in Figure 3.9 is as follows. The programmable command generator is controlled via the HPIB from the HP310 computer. The programmed displacement waveform is sent to the servo system controller electronics. The 32 channels of data are sampled using the two Infotek, 16 channel A/D subsystems. The data is transferred to the computer random access memory (RAM). At completion of the test the data are then transferred to the computer hard disk. For archival purposes the data are transferred to floppy disks.

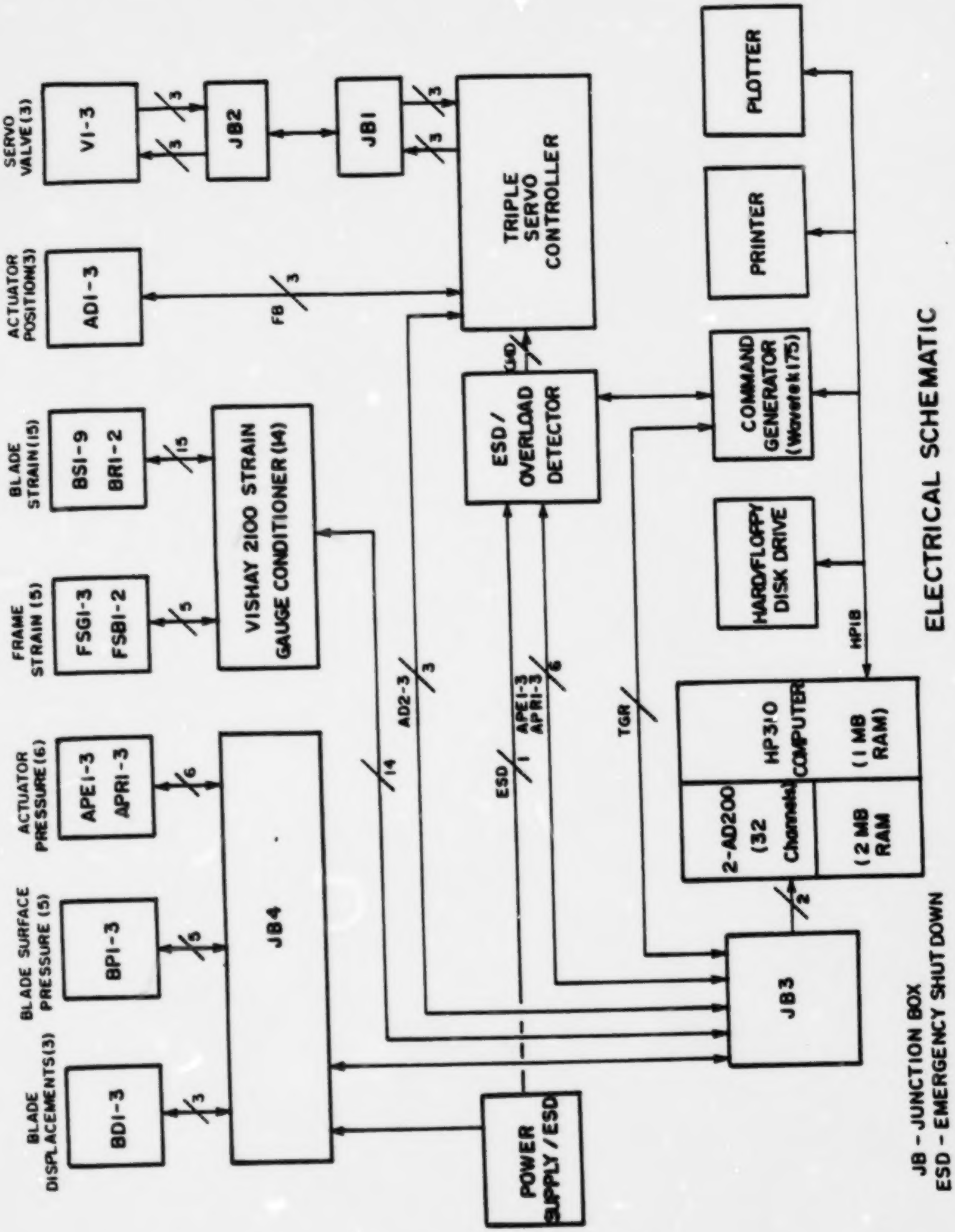
If an overload condition is detected by the analogue overload detector then the displacement command signal is reset to zero, thereby causing retraction of the actuator. The overload detector was analogue rather than computer digital since

Sensor Designation: BACK BLADE (COMPRESSION SIDE) 23 APRIL '88


299 mm
760 mm
6 mm
P7/BP1
P8/BP2
278 mm
582 mm
384 mm
S7/BS1
P9/BP3
S8/BS2
1190 mm
284 mm
765 mm
P10/BP4
P11/BP5
132 mm
350 mm
S9/BS3
S10/BS4
555 mm
274 mm
210 mm
S13/BS7
S11/BS5
S12/BS6
257 mm
395 mm
S14/BS8
260 mm
S1 - S3/BR1 A,B,C

LOCATION OF STRAIN GAUGE ON BLADE COMPRESSION SIDE PLUS CONNECTIONS TO PRESSURE CELLS ON TENSION SIDE

Figure 3.8


BLADE DISPLACEMENTS (3)
BDI-3
BLADE SURFACE PRESSURE (5)
BPI-3
ACTUATOR PRESSURE (6)
APEI-3
APRI-3
FRAME STRAIN (5)
FSGI-3
FSBI-2
BLADE STRAIN (15)
BSI-9
BRI-2
ACTUATOR POSITION (3)
ADI-3
SERVO VALVE (3)
VI-3
3
5
6
5
15
3
3
3
3
JB4
VISHAY 2100 STRAIN GAUGE CONDITIONER (14)
JB2
JB1
FB
3
TRIPLE SERVO CONTROLLER
CMD
ESD / OVERLOAD DETECTOR
14
AD2-3
3
ESD
1
APEI-3
APRI-3
6
TGR
POWER SUPPLY / ESD
JB3
2
2-AD200 (32 Channels)
(2 MB RAM)
HP310 COMPUTER
(1 MB RAM)
HARD/FLOPPY DISK DRIVE
HPIB
COMMAND GENERATOR (Wavetek 175)
PRINTER
PLOTTER
JB - JUNCTION BOX
ESD - EMERGENCY SHUT DOWN

ELECTRICAL SCHEMATIC

Figure 3.9

TRANSDUCER DESIGNATION TABLE

MNEMONIC	LOCATION	DESCRIPTION
AD1	ACTUATOR 1	ACTUATOR 1 EXTENSIOMETER
AD2	ACTUATOR 2	ACTUATOR 2 EXTENSIOMETER
AD3	ACTUATOR 3	ACTUATOR 3 EXTENSIOMETER
BD1	BLADE EXTENSIOMETER FRAME	BLADE EXTENSIOMETERS
BD2		
BD3		
APE1	ACTUATOR 1	ACTUATOR 1 FRONT PRESS. GAUGE
APE2	ACTUATOR 2	ACTUATOR 2 FRONT PRESS. GAUGE
APE3	ACTUATOR 3	ACTUATOR 3 FRONT PRESS. GAUGE
APR1	ACTUATOR 1	ACTUATOR 1 REAR PRESS. GAUGE
APR2	ACTUATOR 2	ACTUATOR 2 REAR PRESS. GAUGE
APR3	ACTUATOR 3	ACTUATOR 3 REAR PRESS. GAUGE
BP1	BLADE, TENSION SIDE	BLADE SURFACE PRESSURE CELL
BP2		
BP3		
BP4		
BP5		
BR1A	BLADE, COMPRESSION SIDE	90 STRAIN GAUGE ROSETTE
BR1B		
BR1C		
BR2A	BLADE, TENSION SIDE	90 STRAIN GAUGE ROSETTE
BR2B		
BR2C		
BS1	BLADE	SINGLE-AXIS STRAIN GAUGE
BS2		
BS3		
BS4		
BS5		
BS6		
BS7		
BS8		
BS9		

Figure 3.10

the computational overhead involved would have significantly reduced the attainable sampling rate.

The threshold conditions for the overload detector both total load and degree of load symmetry, were manually set prior to each test.

The listing of the data acquisition and data reduction software are provided in Appendix A.4.

3.7 Measurement Cycle

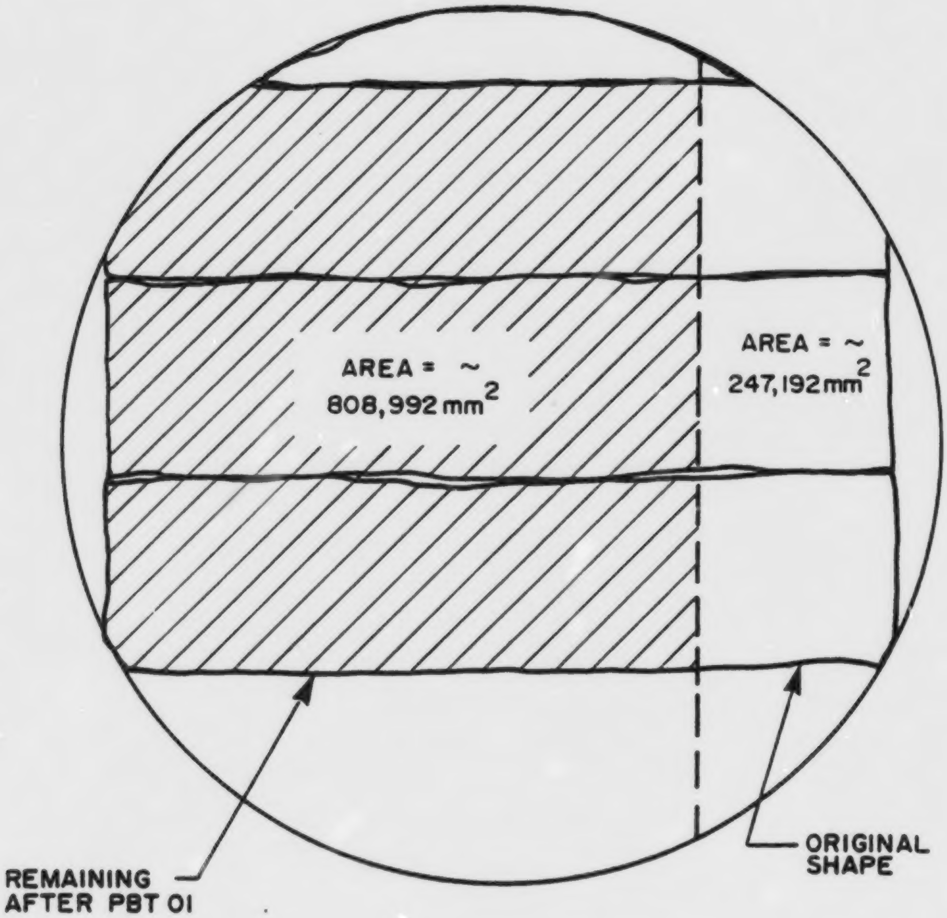
The measurement cycle consisted of the following major steps:

- Manufacture of ice block within ice bucket
- Mounting of ice bucket on test frame
- Load blade
- Documentation of ice failure
- Review of test data

3.7.1 Manufacture of Ice Block

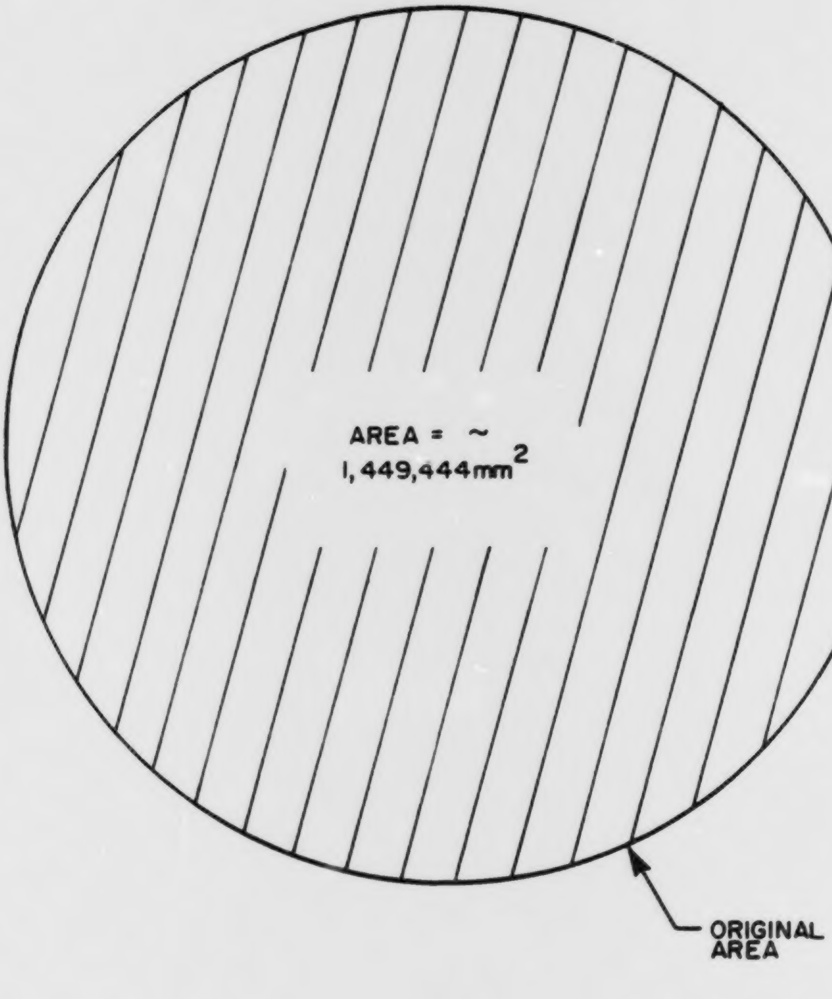
The ice block was manufactured in GEOTECH's cold room. The temperature was generally set to -20°C. The ice blocks were manufactured using fresh water ice. The ice block for test #1 used solid ice blocks of about 4'x2'x1' dimension from a commercial source. Four of these blocks were placed in the bucket and the remaining space filled with an ice/water mixture. The ice/water mixture was applied in layers of about 10cm and allowed to freeze between applications. The surface of the final ice block was then trimmed and contoured to the required shape using chain saws and ice picks.

The ice block #1 proved to be brittle and subsequent ice blocks were manufactured using commercial crushed ice and water. In most cases some of the crushed ice from a previous test was recycled into the next block. The shape of the ice block is given in Figures 3.11 to 3.20.


AREA = ~
808,992 mm^2
AREA = ~
247,192 mm^2
REMAINING
AFTER PBT 01
ORIGINAL
SHAPE

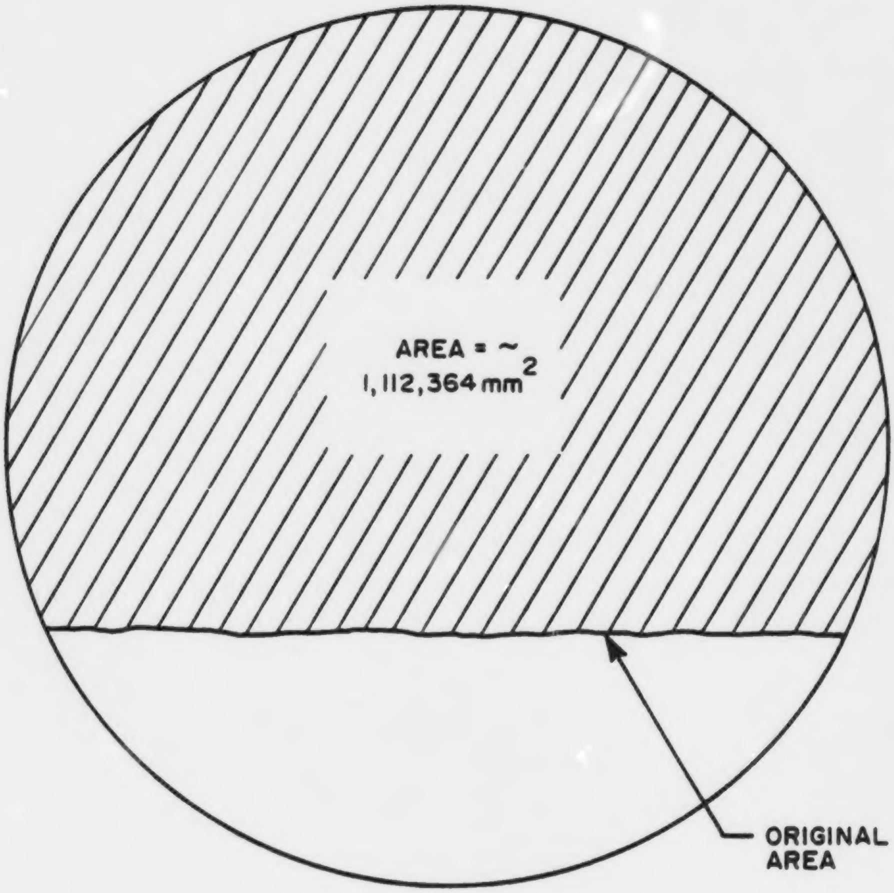
ICE BLOCK PBT 01

Figure 3.11


AREA = ~
1,449,444mm²
ORIGINAL AREA

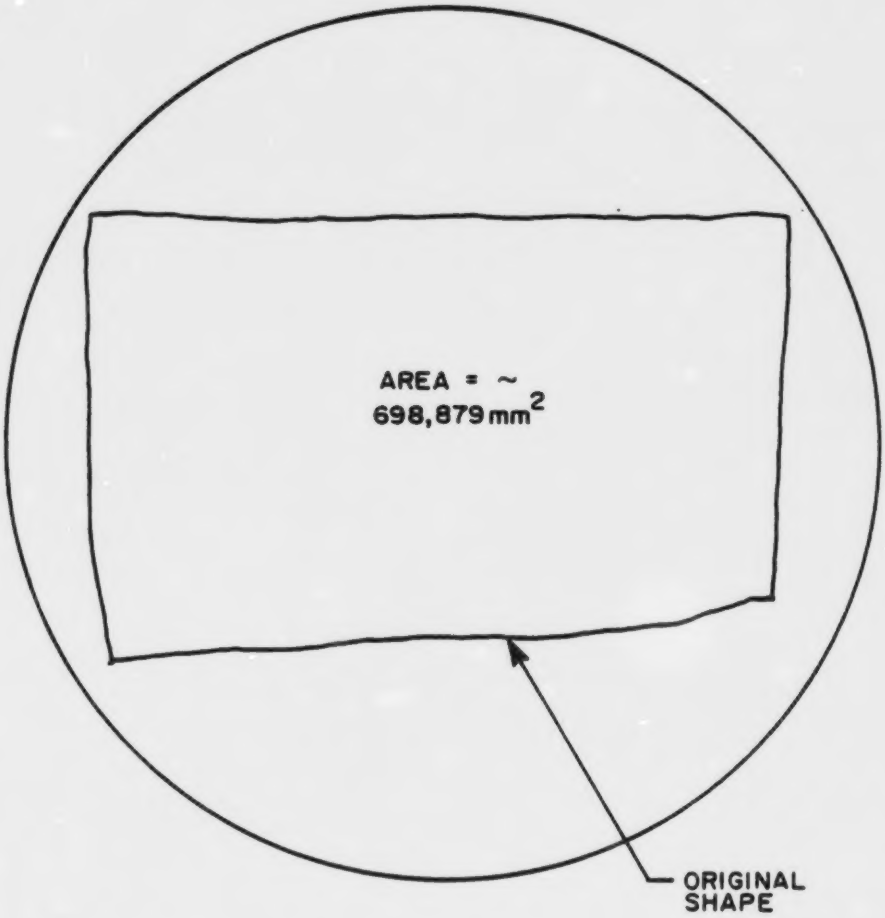
ICE BLOCK PBT 02

Figure 3.12


AREA = ~
1,112,364 mm²
ORIGINAL AREA

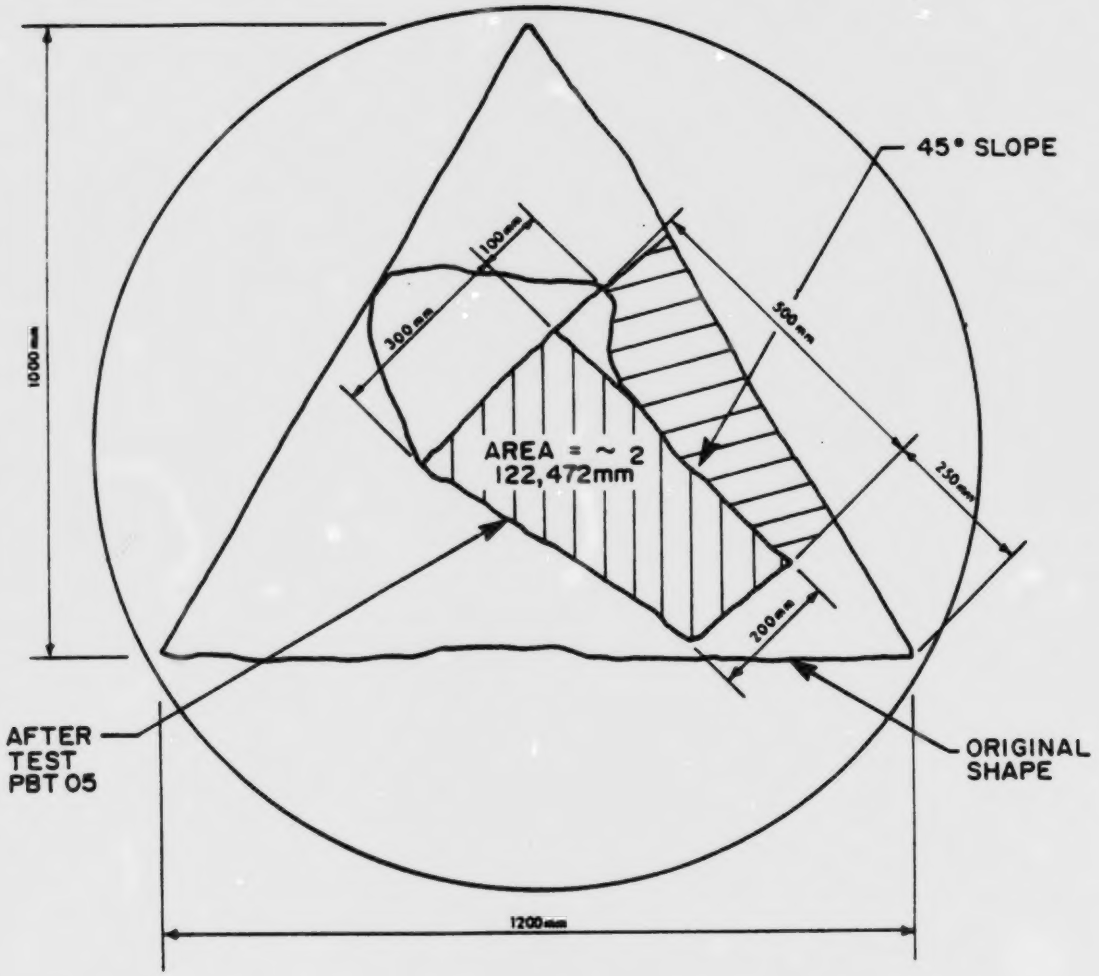
ICE BLOCK PBT 03

Figure 3.13


AREA = ~
698,879 mm^2
ORIGINAL
SHAPE

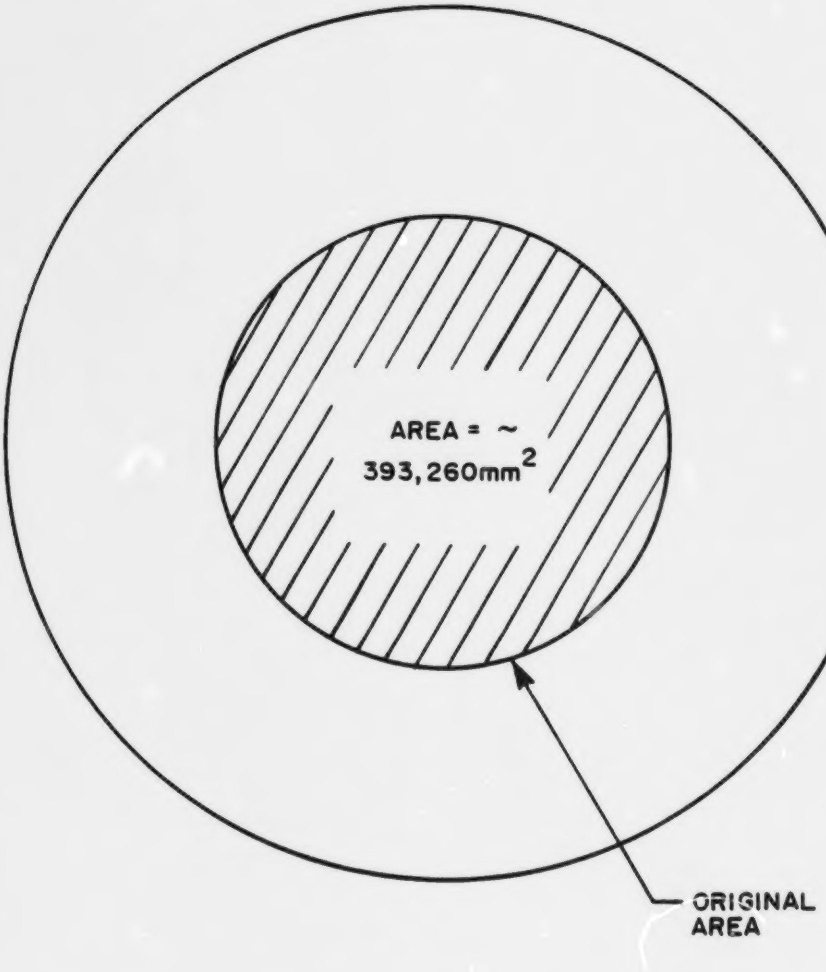
ICE BLOCK PBT 04

Figure 3.14


45° SLOPE
100mm
300mm
500mm
250mm
200mm
1000mm
AREA = ~ 2
122,472mm
AFTER
TEST
PBT 05
ORIGINAL
SHAPE
1200mm

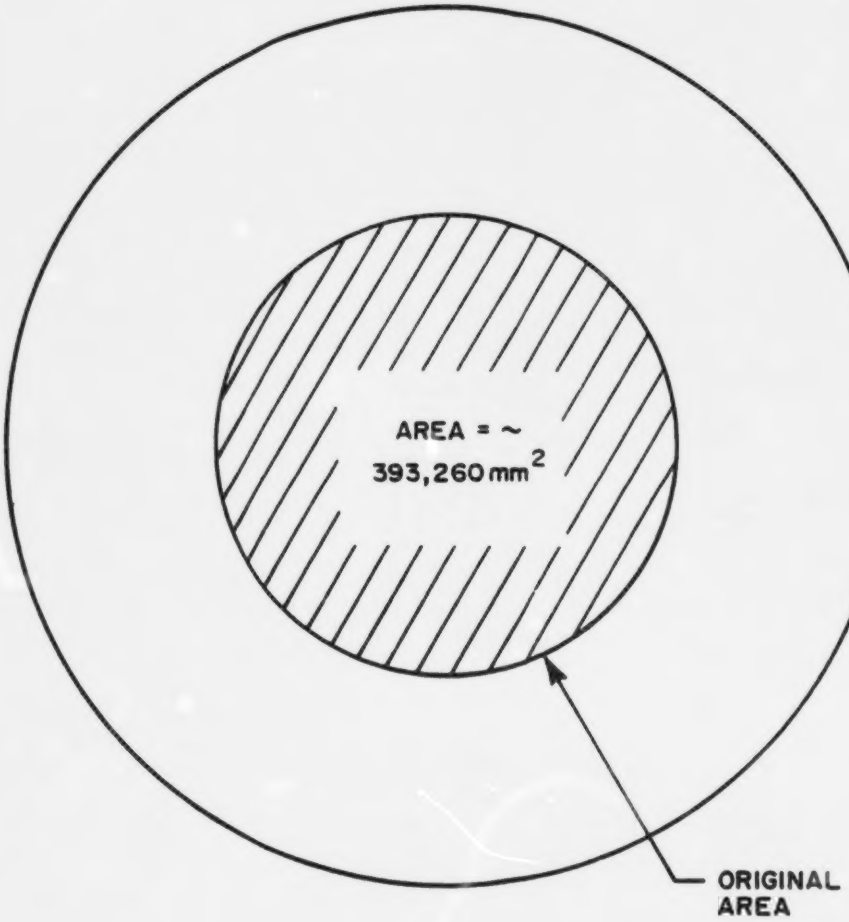
ICE BLOCK PBT 05

Figure 3.15


AREA = ~
393,260mm²
ORIGINAL
AREA

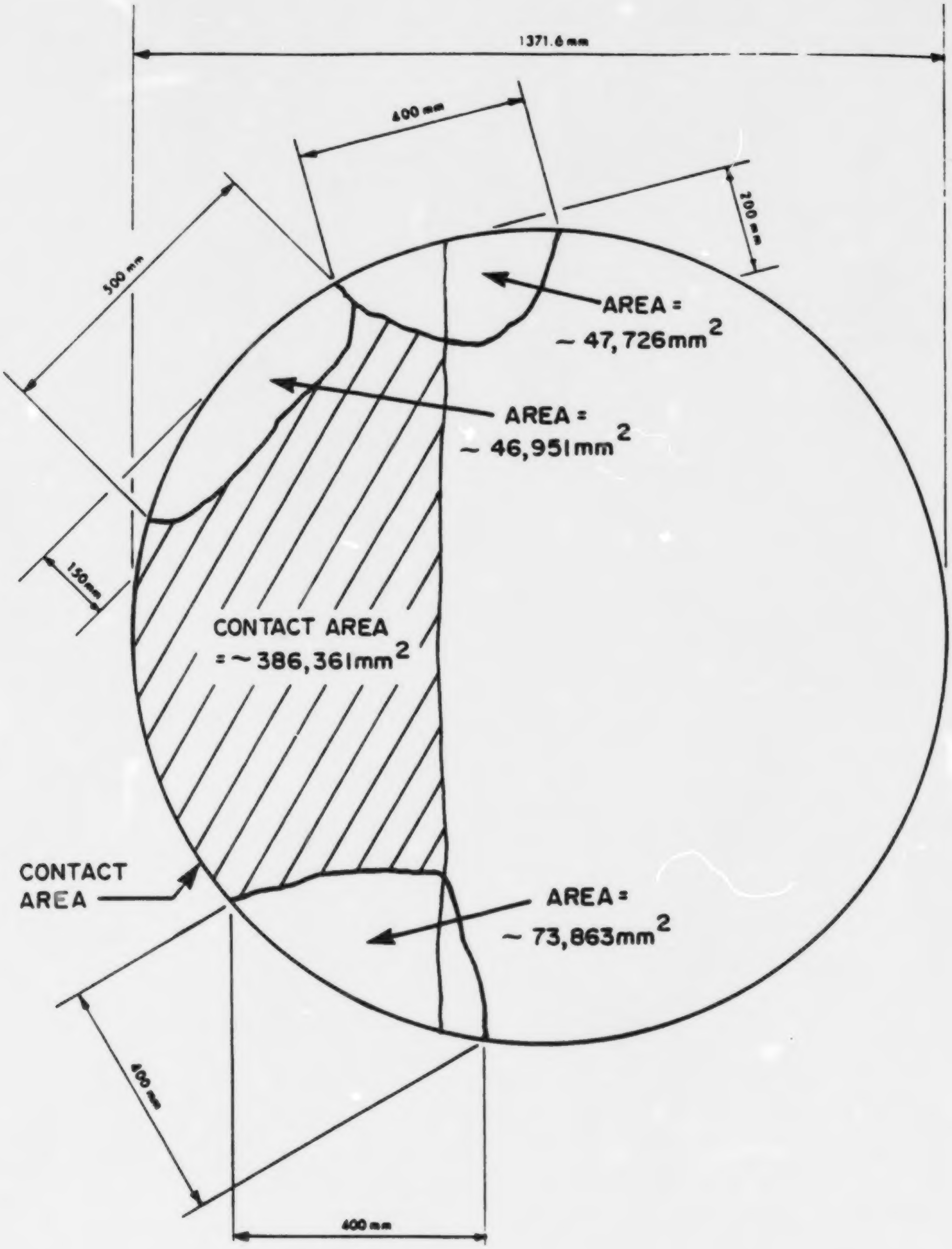
ICE BLOCK PBT 07

Figure 3.16


AREA = ~
393,260 mm^2
ORIGINAL
AREA

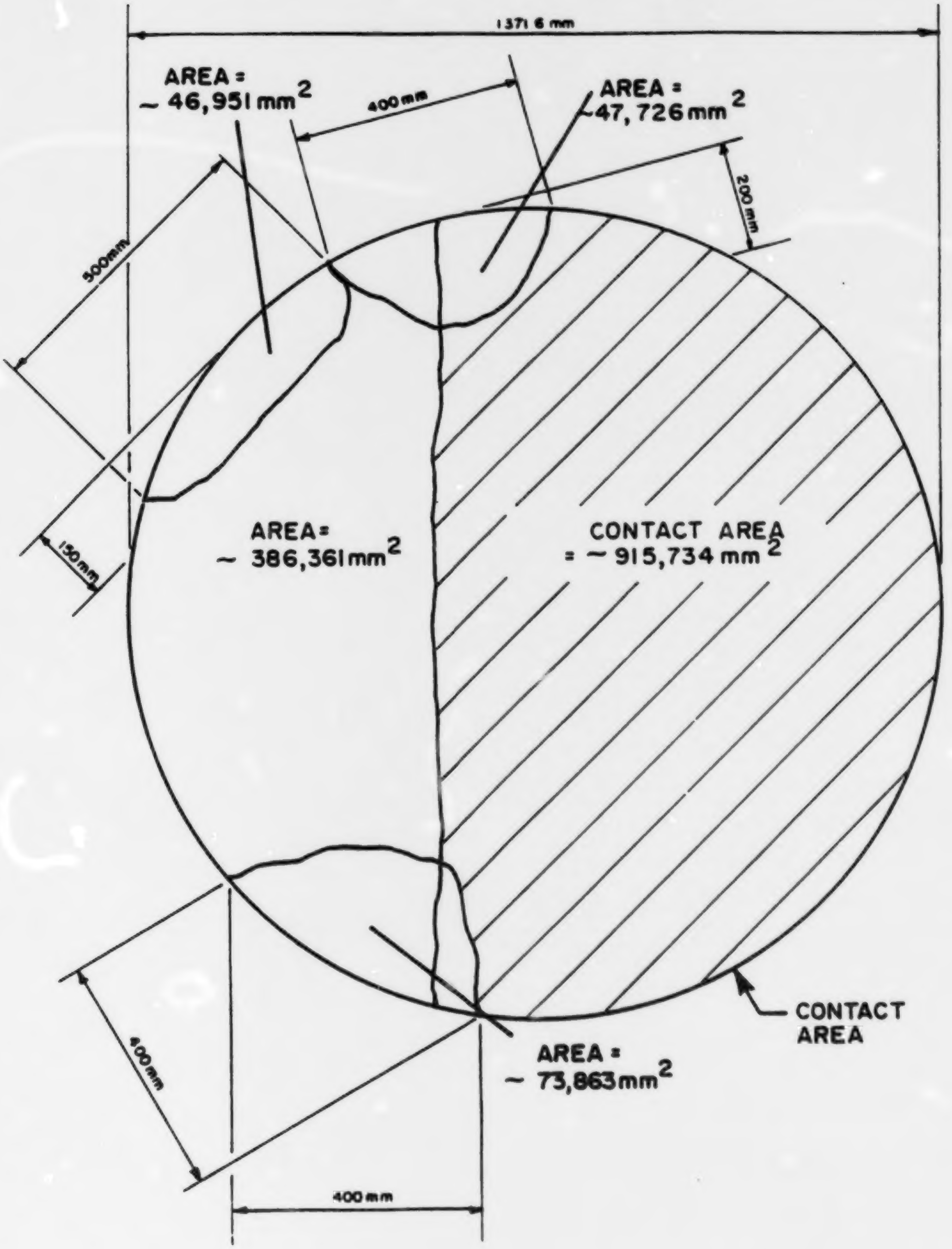
ICE BLOCK PBT 08

Figure 3.17


1371.6 mm
400 mm
200 mm
300 mm
AREA = ~ 47,726mm^2
AREA = ~ 46,951mm^2
150 mm
CONTACT AREA = ~ 386,361mm^2
CONTACT AREA
AREA = ~ 73,863mm^2
400 mm
400 mm

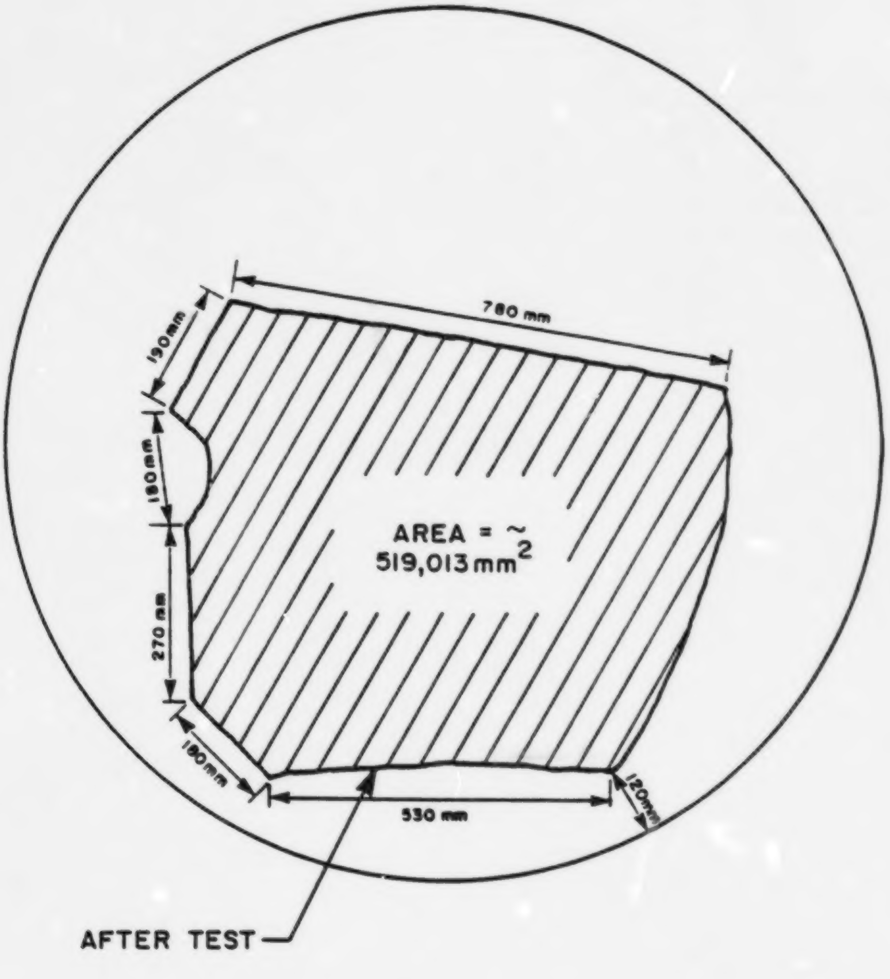
ICE BLOCK PBT 09

Figure 3.18


1371.6 mm
AREA =
~ 46,951 mm^2
400 mm
AREA =
~47,726 mm^2
200 mm
500mm
150mm
AREA =
~ 386,361 mm^2
CONTACT AREA
= ~ 915,734 mm^2
CONTACT
AREA
AREA =
~ 73,863 mm^2
400mm
400 mm

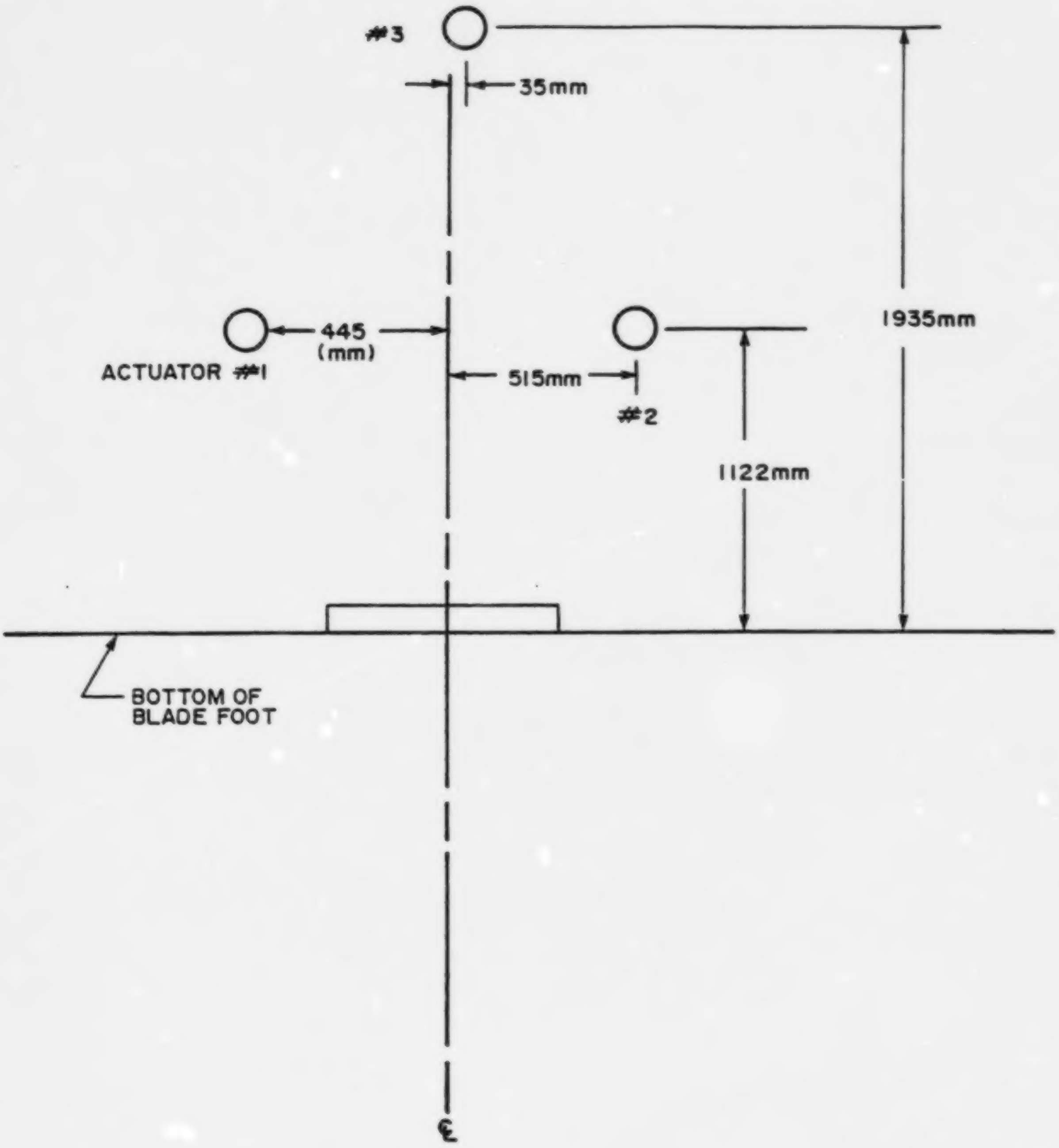
ICE BLOCK PBT 10

Figure 3.19


780 mm
190mm
180mm
270 mm
180mm
530 mm
120mm
AREA = ~
519,013 mm²
AFTER TEST

ICE BLOCK PBT 15

Figure 3.20

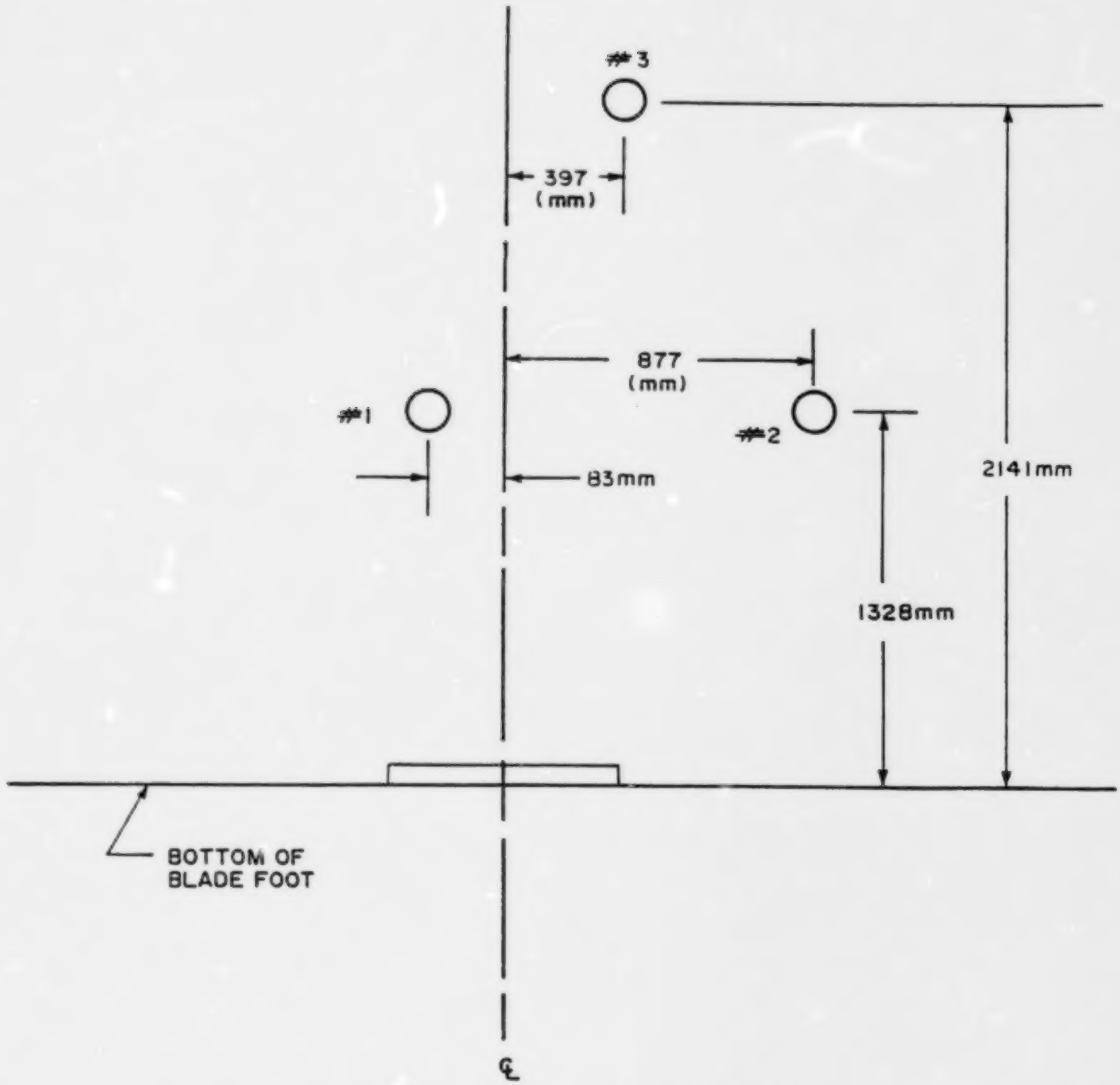

#3
35mm
445 (mm)
ACTUATOR #1
515mm
#2
1122mm
1935mm
BOTTOM OF BLADE FOOT
℄

VIEW LOOKING TOWARDS ACTUATOR

TESTS 1 TO 6 INCLUSIVE

P.A.S Nov. 88
9488

Figure 3.21


#3
397
(mm)
877
(mm)
#1
#2
83mm
2141mm
1328mm
BOTTOM OF
BLADE FOOT
℄

VIEW LOOKING TOWARDS ACTUATOR

TESTS 7 TO 19 INCLUSIVE

P.A.S. Nov88
9488

Figure 3.22

3.7.2 Mounting

The ice bucket with its ice was then transported out of the cold room using a fork lift. The fork lift was then used to lift the ice bucket which was then bolted to the actuator skid. The location of the three actuators relative to the blade for tests 1-6 and 7-19 are given in Figures 3.21 and 3.22.

3.7.3 Testing

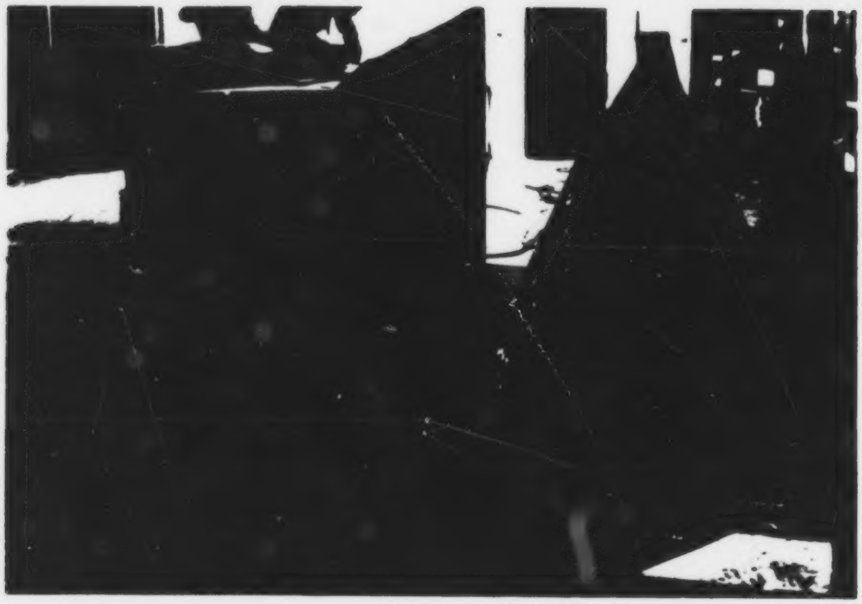
While the ice bucket was being mounted the hydraulic accumulator system was recharged. The air side of the accumulator only had to be charged once at the beginning of the test programme. A slow leak meant that it had to be partially recharged every few days. The complete charging of the air side took approximately 12 hours. The oil side of the accumulators were charged prior to each test. This charging took up to one hour depending upon the volume of oil used in the previous test.

The actual test only took a few seconds. Data was available for inspection by the computer within a few minutes of the testing.

The shape of the remaining ice block was documented by photographic means or by measuring the features of the ice block. Photographs were also taken to illustrate the size of the broken ice pieces.

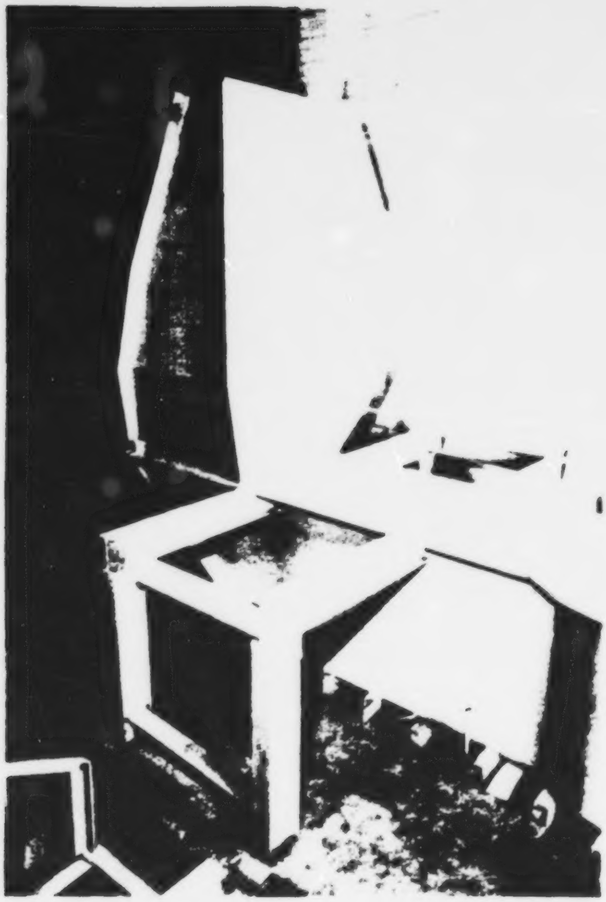
4.0 PHOTOGRAPHS ILLUSTRATING THE PROJECT

In this section are photographs illustrating the project. The photographs are organized to show the manufacture of the test frame, then details of the various instrumentation systems and sensors, then some representative examples of the ice interaction.

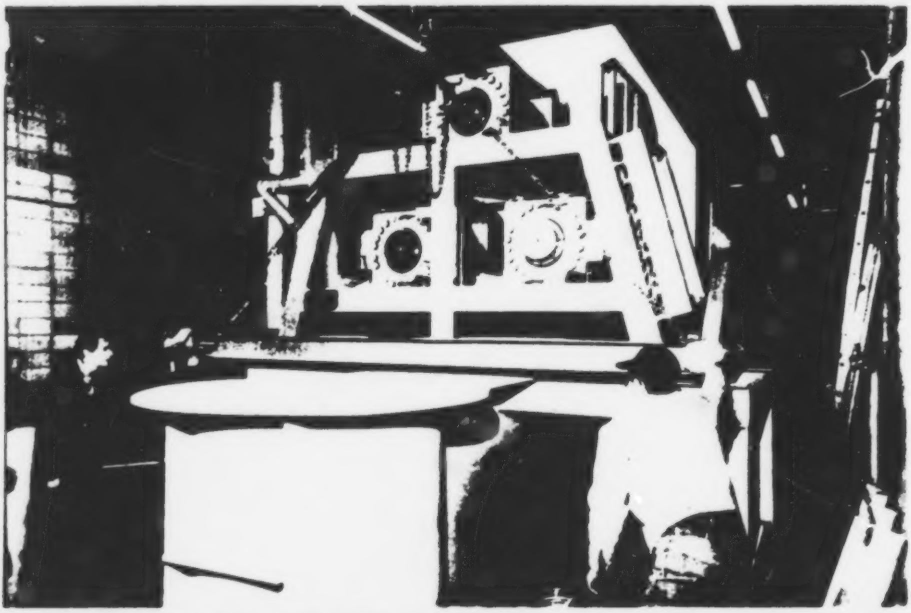


DURING CONSTRUCTION OF FRAME SHOWING DETAILS OF THE CONSTRUCTION OF THE BACKSTOP

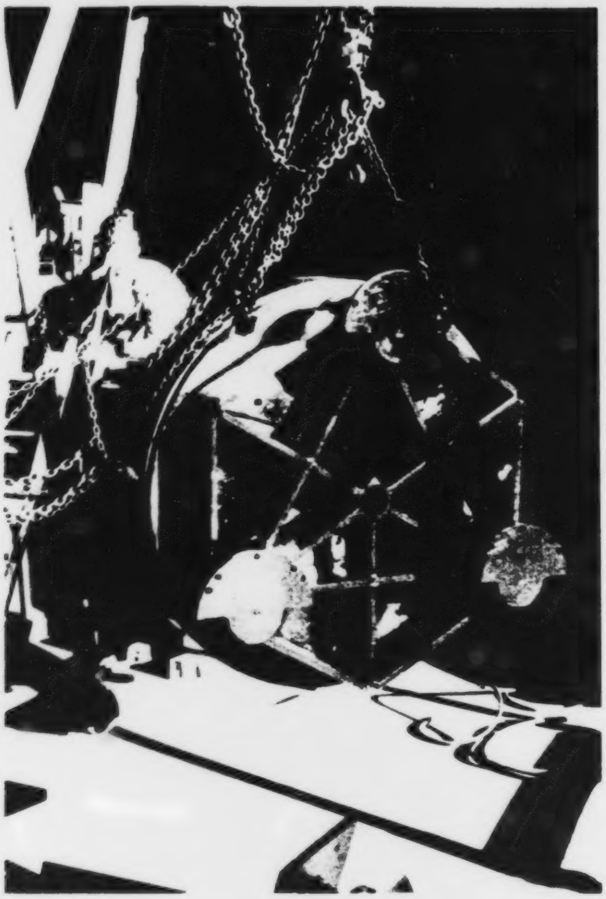
BACKSTOP BEING WELDED TO THE MAIN GIRDER



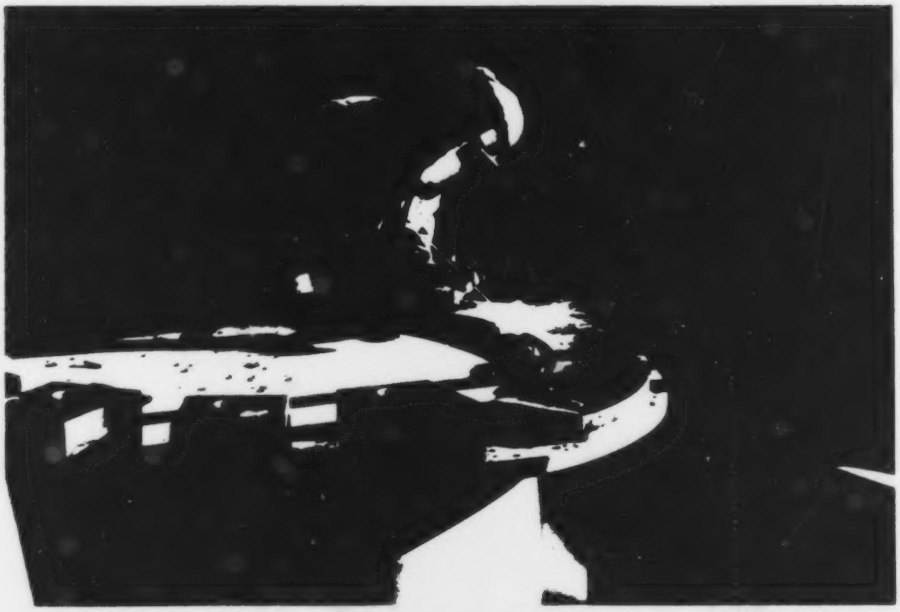
BACKSTOP MOUNTED ON THE MAIN GIRDER AFTER PAINTING. THE I BEAMS PROVIDE SUPPORT FOR THE ACTUATOR ASSEMBLY. WOODEN WEDGES UNDER MAIN GIRDER USED FOR LEVELLING AND UNIFORM DISTRIBUTION OF LOAD ON CONCRETE FLOOR



LIFTING TRIPLE ACTUATOR ASSEMBLY ONTO TEST FRAME. BLADE MOUNTING HARDWARE NOT INSTALLED YET



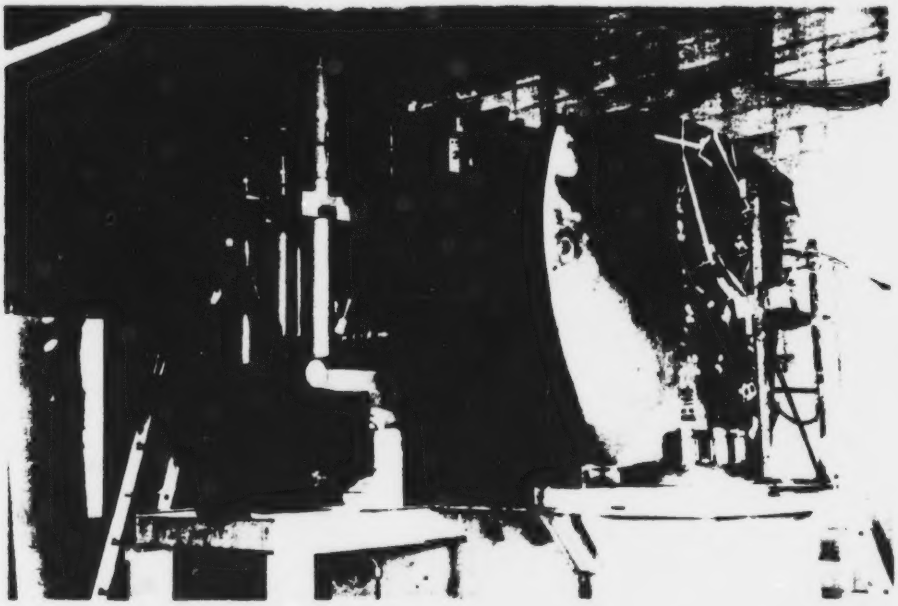
BACK VIEW OF ICE BUCKET SHOWING EXTENSIVE STIFFENING AND MOUNTING PLATES



DURING ASSEMBLY OF BLADE MOUNTING HARDWARE

PROPELLER BLADE BOLTED TO 100mm CIRCULAR BOX PLATE. ARC ON THE RIGHT HAND SIDE RESISTS AXIAL THRUST

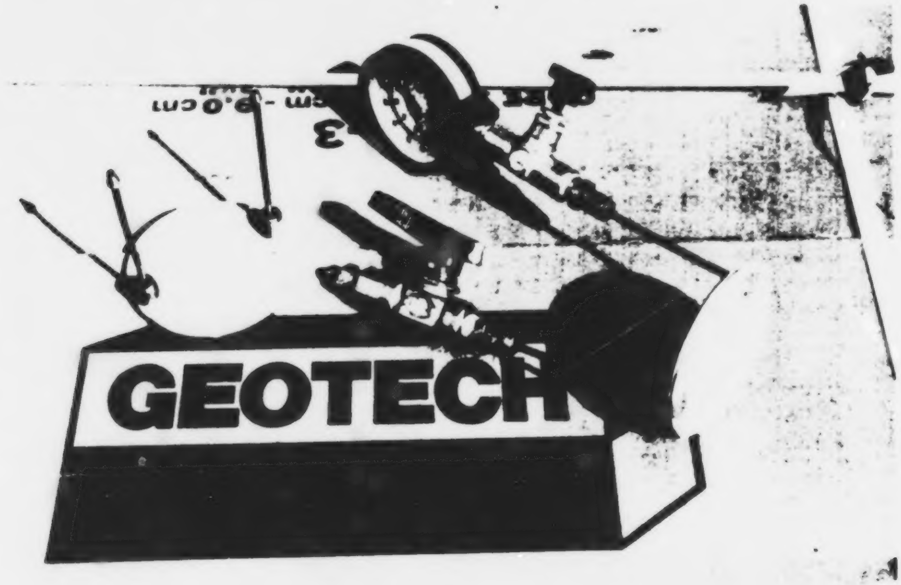
GENERAL ARRANGEMENT SHOWING REACTION FRAME, ACTUATOR SKID AND INSTRUMENTED PROPELLER BLADE



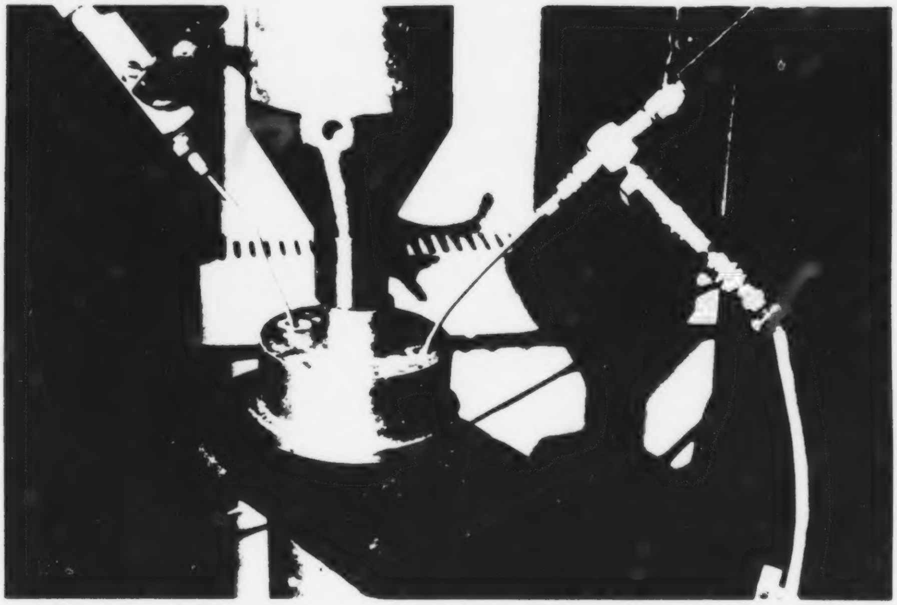
GENERAL ARRANGEMENT SHOWING INSTRUMENTATION ON PROPELLER BLADE

TIGHTENING BLADE ONTO THE MOUNTING PLATE

MACHINING OF RECESSES IN PROPELLER BLADE TO ACCOMMODATE BLADE PRESSURE CELLS

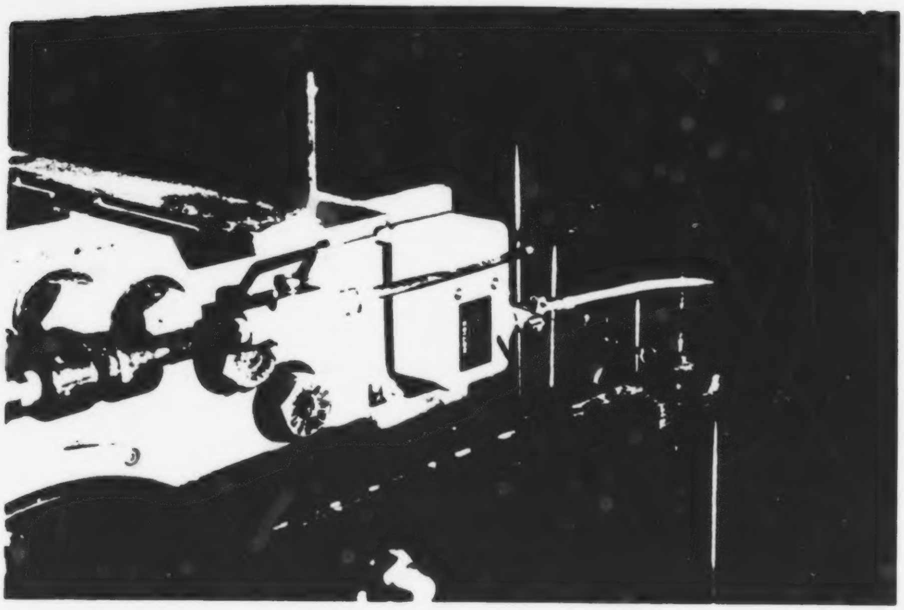


GENERAL ARRANGEMENT OF PROPELLER BLADE PRESSURE SENSORS DURING FITTING PROCESS. THE DIAL GAUGE IS FOR TEMPORARY USE ONLY



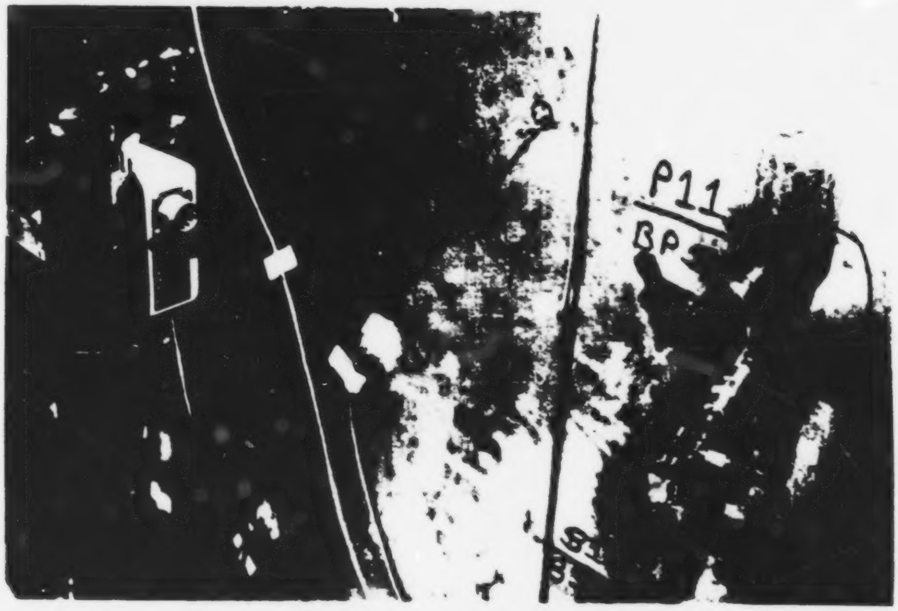
LABORATORY TESTING OF LOCAL PRESSURE CELL, MOUNTED WITHIN TRIAXIAL TEST FRAME

LABORATORY TESTING OF BLADE PRESSURE CELL



DISPLACEMENT TRANSDUCER USED TO CONTROL THE MOTION OF AN ACTUATOR

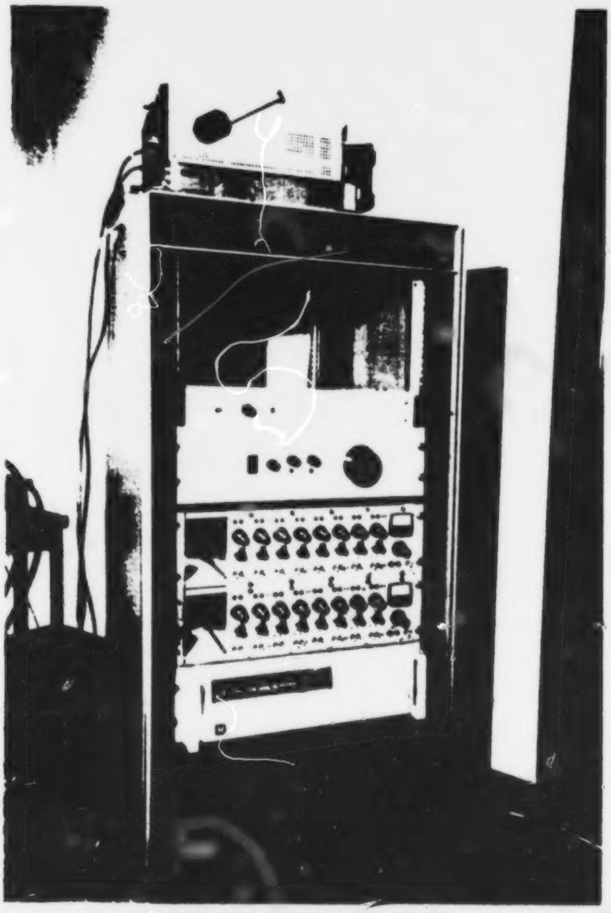
APPLICATION OF BONDABLE STRAIN GAUGES TO SURFACE OF PROPELLER BLADE



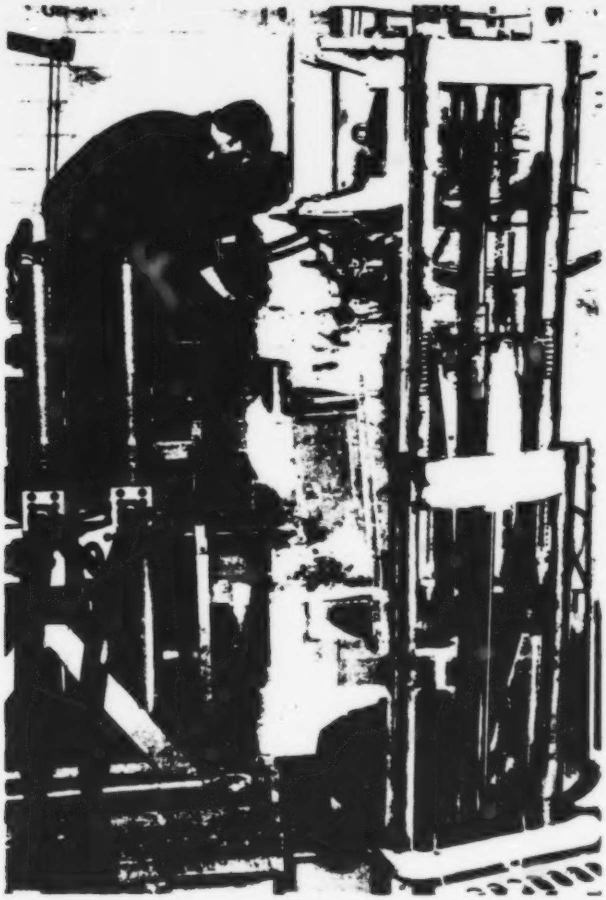
VIEW OF PROPELLER BLADE SHOWING DISPLACEMENT TRANSDUCERS FOR BLADE DEFLECTION, THE DETAILS OF THE TRANSDUCER CONNECTION FOR THE COMPLETED BLADE PRESSURE TRANSDUCERS AND SOME TO THE BONDABLE STRAIN GAUGES

FRONT VIEW OF BLADE PRESSURE TRANSDUCERS NUMBER BP2. THE PRESSURE CELLS ARE CONSTRUCTED FROM STAINLESS STEEL

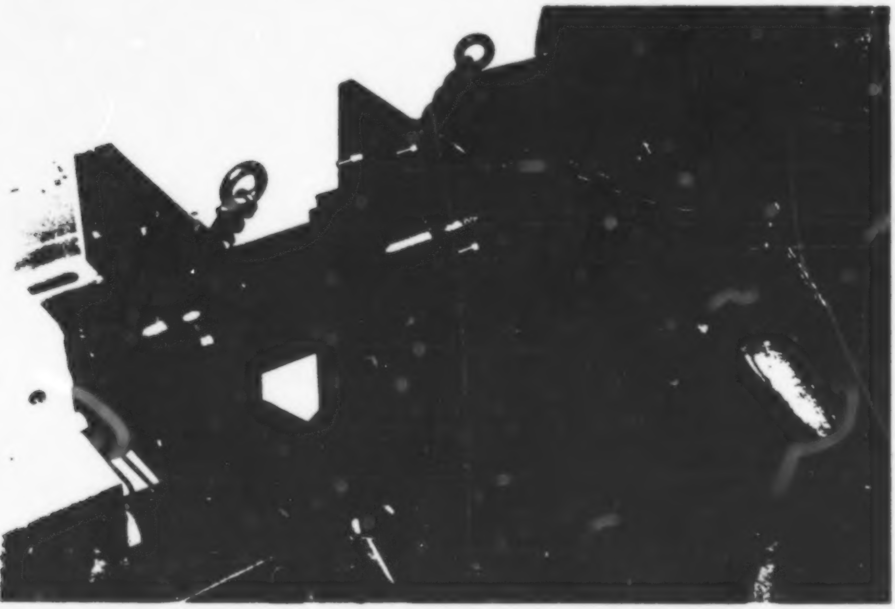
DATA ACQUISITON SYSTEM SHOWING HP310 SERIES COMPUTER AND THE TRIPLE SERVO CONTROLLER BOX



EQUIPMENT RACK SHOWING, FROM TOP DOWN, THE OVERLOAD EMERGENCY SHUT DOWN BOX. VISHAY 2100 SERIES STRAIN GAUGE SIGNAL CONDITIONER. WAVETEK PROGRAMMABLE FUNCTION GENERATOR



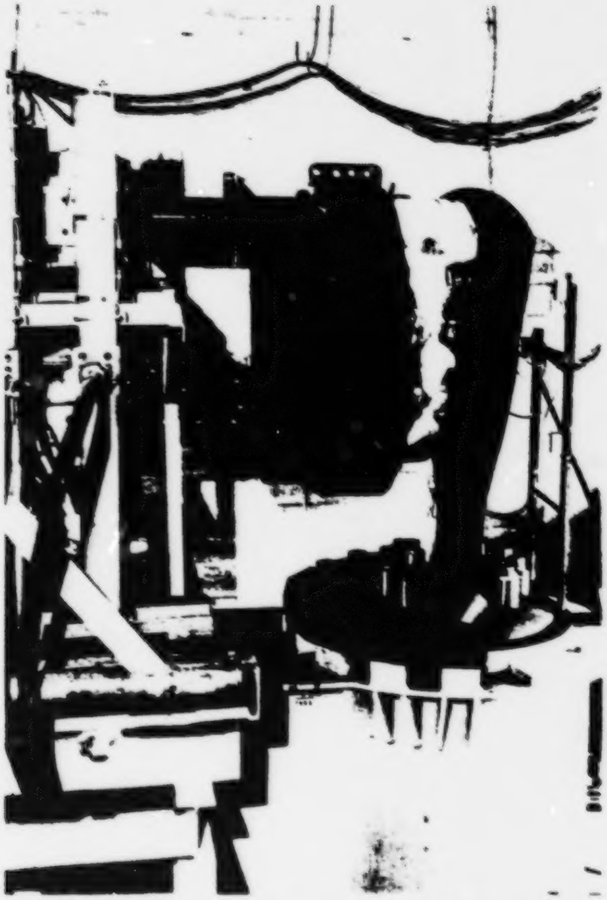
USE OF FORK LIFT TO MATE THE ICE BUCKET AND THE ICE BLOCK TO THE ACTUATOR SKID



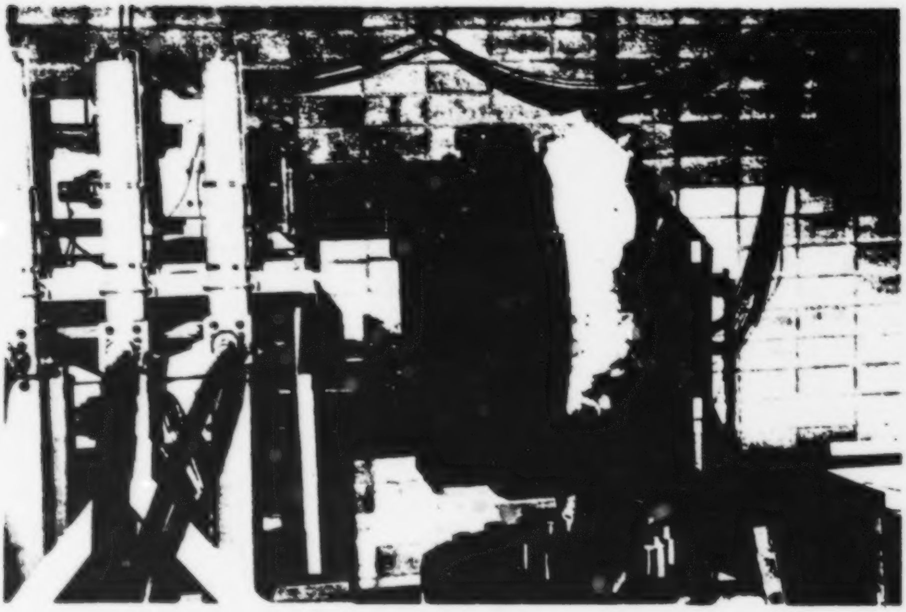
DETAILS OF CONNECTION BETWEEN ICE BUCKET NOTE BOLTED CONNECTED DESIGNED FOR COMPRESSION ONLY. BOLTS FAILED DURING TEST #19

SHAPING OF ICE BLOCK IN COLD ROOM

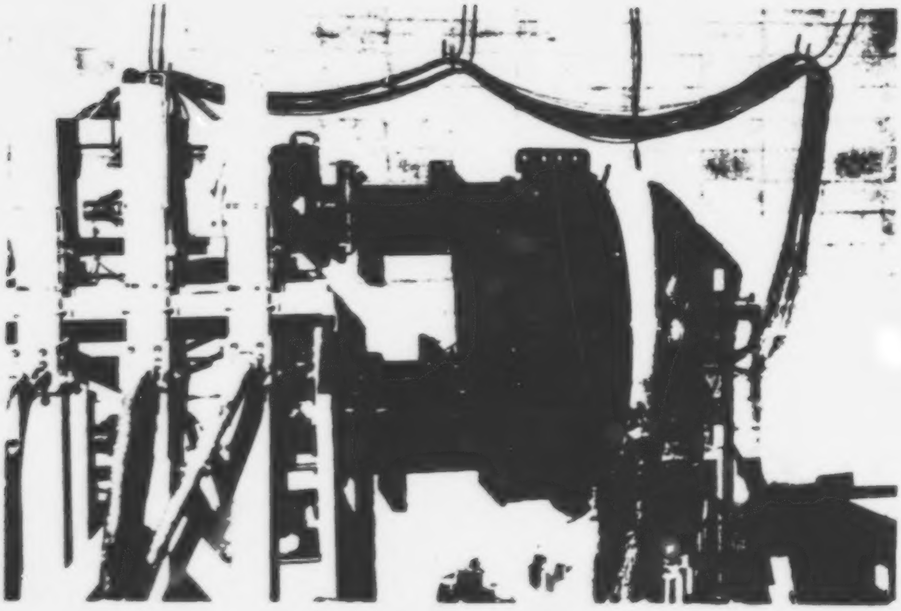
MANUFACTURE OF ICE BLOCK IN COLD ROOM



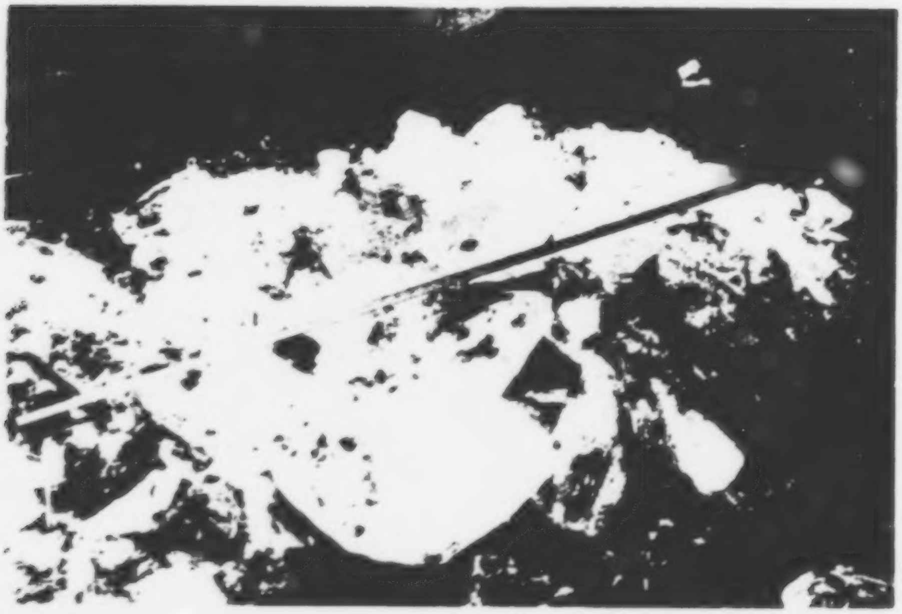
ICE BLOCK FOR TEST # 1 PRIOR TO IMPACT.
NOTE FRONT SURFACE OF ICE BLOCK
CONTOURED TO BLADE SURFACE



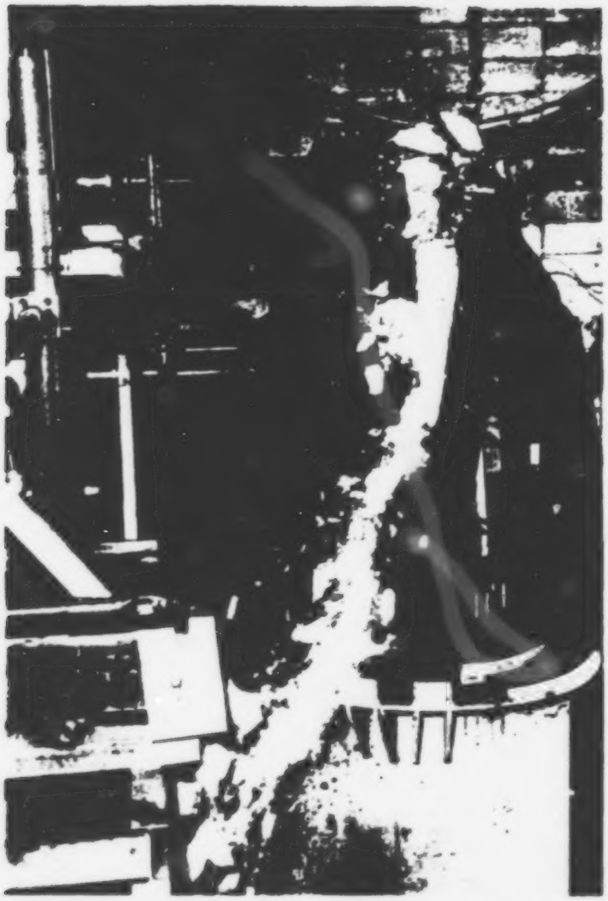
INITIAL IMPACT FOR TEST #1



AT END OF TEST #1 , NOTE THAT THERE IS NO CONTACT BETWEEN THE ICE BUCKET AND THE PROPELLER BLADE

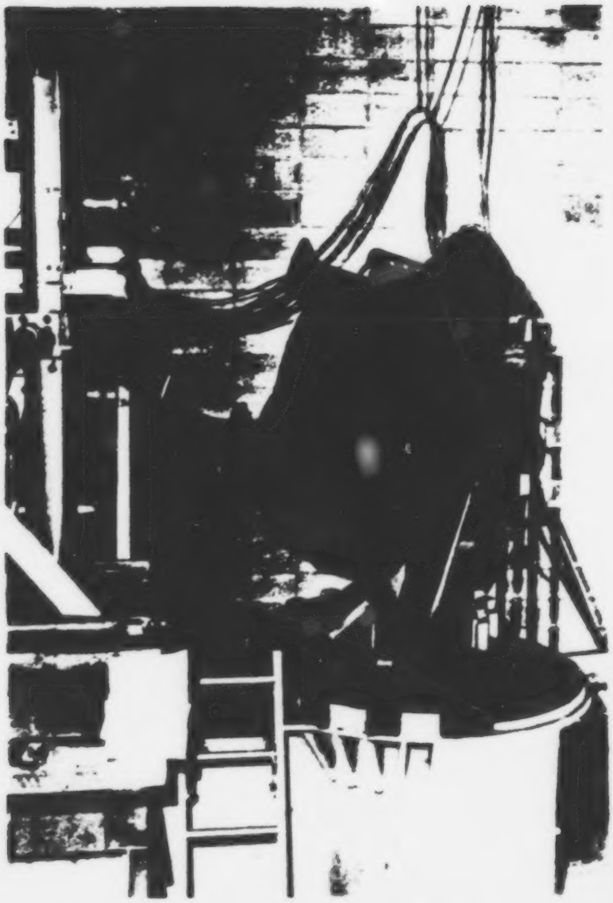


ICE BLOCKS CREATED BY TEST #1



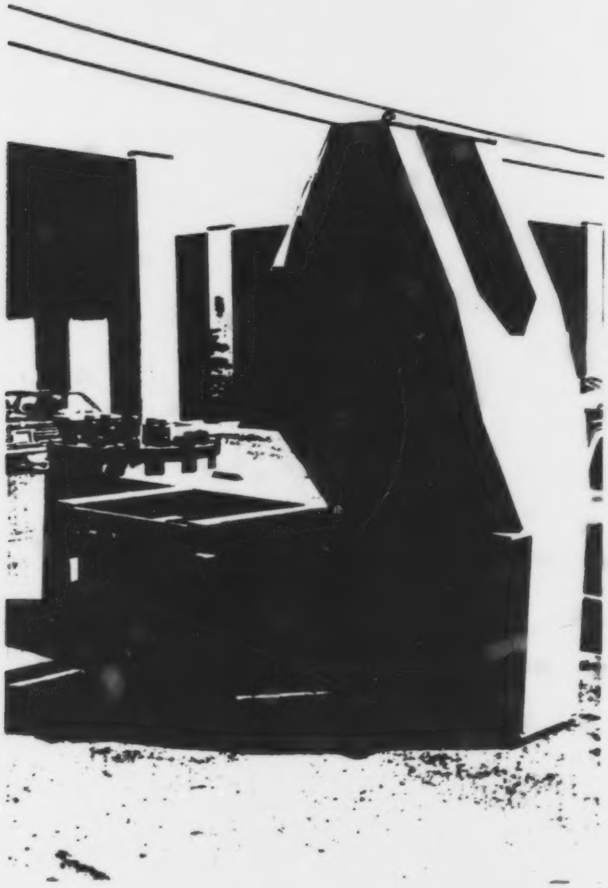
EJECTION OF ICE DURING INITIAL IMPACT OF TEST #9

WOOD ASSEMBLY USED FOR TEST #19



AFTER THE WOOD BLOCK SLIPPED OUT FROM THE ICE BUCKET THE BOLTS FAILED CONNECTING THE ICE BUCKET TO THE ACTUATOR

SOME WOOD REMAINING AFTER TEST #19



TEST FRAME AFTER COMPLETION OF THE IMPACT TEST

5.0 CONCLUSIONS

The conclusions arising out of Volume I: Data Collection Report are summarized below:

- A test apparatus was constructed which simulated the interaction between a non-rotating propeller blade and a massive ice feature.
- The blade was loaded to such an extent that permanent (non-elastic) blade deformation occurred.
- A total of 18 successful tests were conducted.
- The blade was loaded using ice and using wood. With ice both ductile and brittle ice behaviour was observed.
- Pressure distributions in the interaction zone were recorded.
- Blade strain and deflections were recorded during both elastic and non-elastic blade behaviour.
- The applied loading was recorded on a common time base with the blade response.
- The dynamical properties of the blade were evaluated by hammer tests applied to the blade surfaces.

6.0 RECOMMENDATIONS

The recommendations are deferred to Volume II to which the reader is directed.

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1. "A Study of Ice Class Rules for Propellers", P. Noble and V. Bulat, SNAME Transactions, 1981.

2. "The Shipping Crisis in the Soviet Eastern Arctic at the Close of the 1983 Navigation Season", W. Barr and E.A. Wilson, Arctic Volume 38 #1, pp 1-17, 1983.

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6. "Ice Mechanics", B. Michel, Les Presses de Universite Laval, 1983.

7. "The Dimensioning of High Power Propeller Systems for Arctic Icebreakers and Icebreaking Vessels", J.Wind, 5th LIPS Propeller Symposium, Holland, May 1983.

8. "Robert Lemeur Ice/Propeller Interaction", Canadian Marine Drilling for TDC. Report TP 6176/77/78, 1985.

9. "Propeller Ice Interaction: An Investigation Into Propeller Ice Forces", TDC Report Martec Ltd. TP4022E, 1982.

10. "Updating the Canadian Ice Class Rules Through Research and Development", J. Grinstead International Polar Transportation Conference, Vancouver, Canada, May 1986.

11. "M.V. Canmar Kigoriak Propeller Characteristics", LIPS Propeller Work Published with permission of Dome Petroleum Ltd. 1979

12 "Kigoriak and Robert Lemeur 1983 Full Scale Impact Tests", Canadian Marine Drilling Ltd., TDC Report TP5378E, 2 Volumes 1984/5

13. "Failure Criteria for Multi-Year Ice Based on Medium Scale Field and Small Scale Laboratory Tests", D.M. Masterson and S.H. Iyer, I.A.H.R. Ice Symposium, Sapporo, Japan. 1988.

14. Personal Communication Clive Brown, Canadian Marine Drilling Ltd., 1988

15. "Evaluation of Sensors for Measuring Pack Ice Forces", Paul Spencer, GEOTECHnical resources ltd. report for National Research Council, April 1988.

16. "Formulae for Stress and Strain", R.J. Roark and W.C. Young, McGraw-Hill Book Company, 5th Edition, 1982

APPENDIX A

1.0 Machine Drawings
2.0 Non Destructive Testing on Propeller Blade
3.0 Overload Detector Schematics
4.0 Software Listing
5.0 Calibration Data on Blade Pressure Cells
6.0 Blade Test Data Plots
7.0 Fourier Transform of Blade Hammer Tests
8.0 Minimum and Maximum Values of Data Plots
9.0 Equipment Specifications

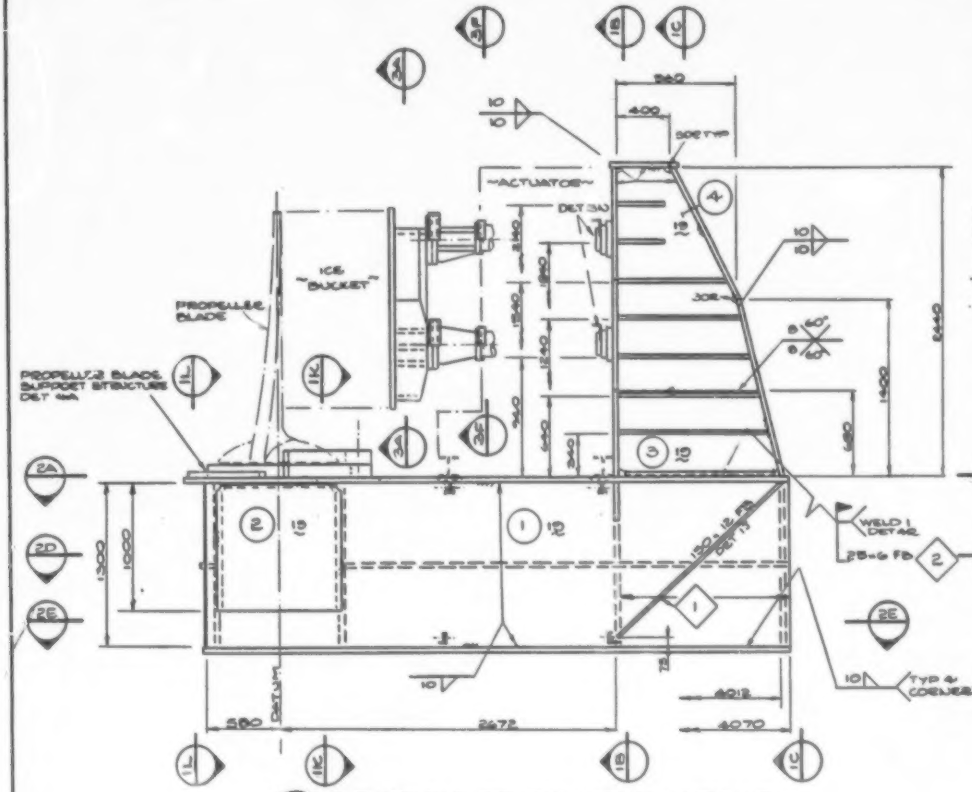
APPENDIX A.1

Machine Drawings

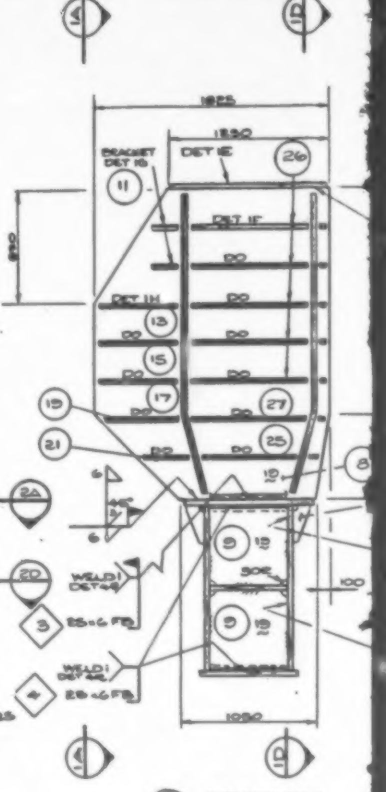
Appendix A:

1.0 MACHINE DRAWINGS

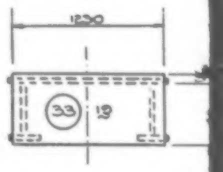
In this section we provide the machine drawings for the reaction frame. The general terms of reference for the design parameters were specified by GEOTECH in consultation with Vlodek Laskow of A.R.A.D., Bragg Creek. The frame was designed by M. Smyth, Calgary and the detailed scantlings and drawings by C. Stanley of C by Design, Calgary. The detailed design of the blade tie down was performed by GEOTECH. Machining of the blade fastening hardware was performed by Adrico, Calgary. The reaction frame was manufactured and assembled by GEOTECH. The machining of the recesses in the propeller blade to accommodate the local pressure cells was performed by Rotating Equipment Services, Calgary. The pressure cells were designed by GEOTECH.


~ACTUATOR~
ICE ~BUCKET~
PROPELLER BLADE
PROPELLER BLADE SUPPORT STRUCTURE DET 4A
DET 3N
960
400
4
3
19
2
1
WELD 1 DET 4R
25x6 FB
TYP 4 CORNERS
150x12 FB DET 1J
1300
1000
580
2672
4012
4070
DATUM
1L
1K
1B
1C
2A
2D
2E
3A
3F

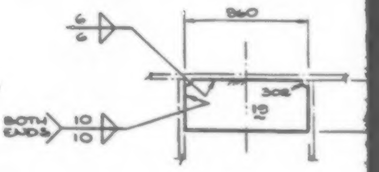
1A ELEVATION OF REACTION FRAME


1825
1350
BRACKET DET 1G
DET 1E
DET 1F
DET 1H
DO
11
13
15
17
19
21
25
26
27
9
WELD 1 DET 4R
25x6 FB
2
3
4
302
100
1050
1A
1D
2A
2D

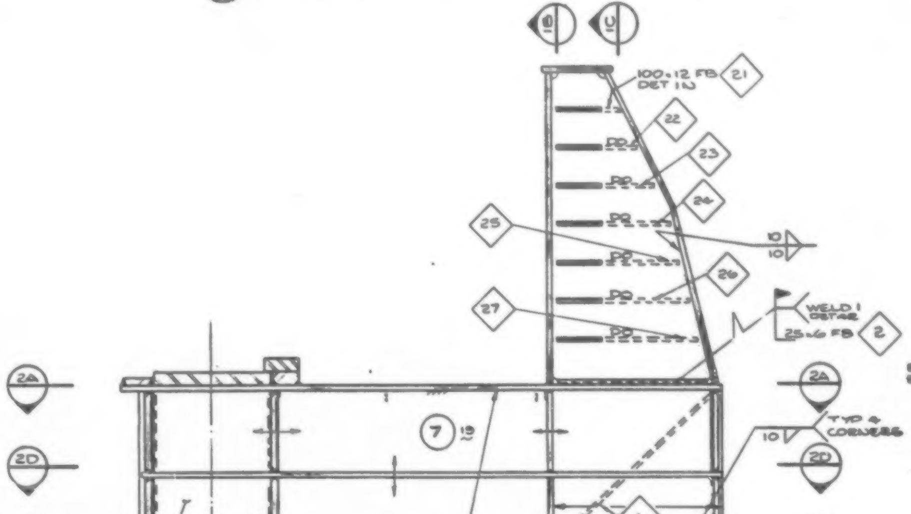
1B SECTION



1E DETAIL

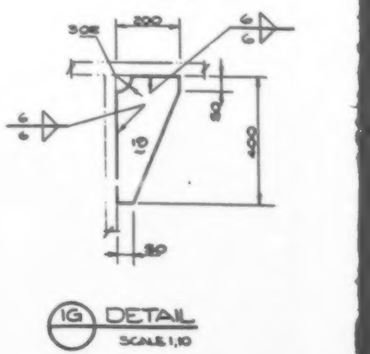

860
6/6
302
19
BOTH ENDS
10/10

1F DETAIL


100x12 FB DET 1N
21
22
23
24
25
26
27
DO
10/10
WELD 1 DET 4R
25x6 FB
2
7
19
TYP 4 CORNERS
1
2 19 PL BEHIND
1B
1C
2A
2D
2E

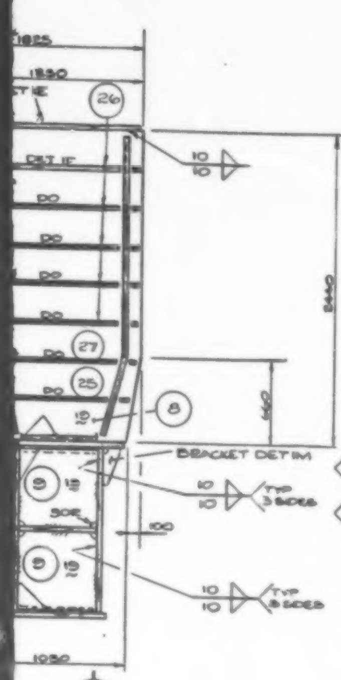
1D ELEVATION OF REACTION FRAME

FOR INFORMATION NOT SHOWN SEE 'IA'

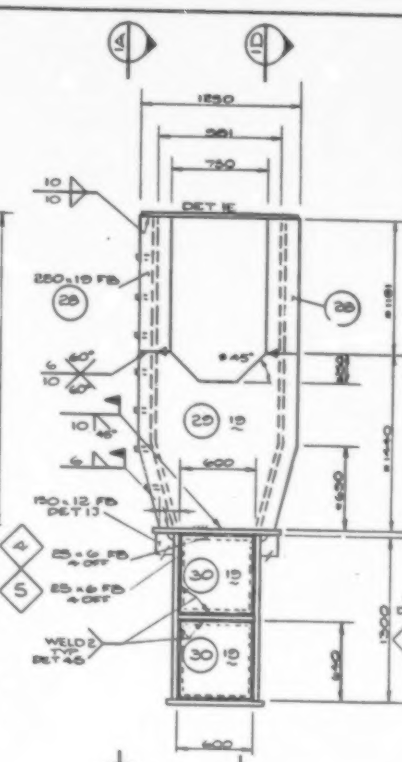

302
200
6/6
30
400
19
30

1G DETAIL

SCALE 1:10

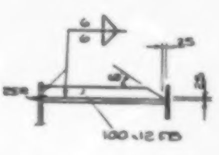

1825
1830
ST IE
26
DET IF
DO
27
25
8
19
BRACKET DET IM
9
19
30R
10 10 TYP 3 SIDES
100
10 10 TYP 3 SIDES
1050
2440
640
ID

SECTION

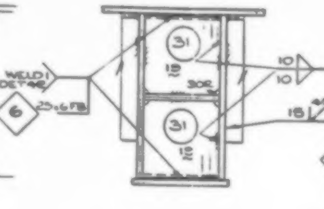

ID
IA
ID
1250
981
780
DET IE
10 10
280x19 FB
28
28
6 10 60°
60°
*45°
29 19
10 45°
6
600
130x12 FB DET IJ
4 25x6 FB 4 OFF
5 25x6 FB 4 OFF
WELD 2 TYP DET 4B
30 19
30 19
400
2440
1300
830
IA
ID

IC SECTION

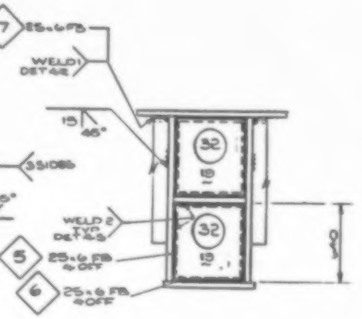
* NOTE: DIMENSION TAKEN ON PLANE OF PLATE AND NOT VERTICAL


6 6
25
25R
60°
100x12 FB

IN DETAIL

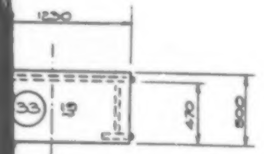

WELD 1 DET 4B
6 25x6 FB
31 19
30R
31 19
10 10 3 SIDES
18 45°

IK SECTION

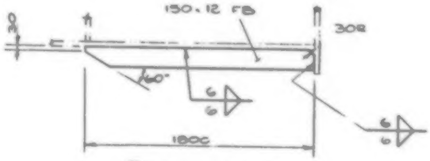

7 25x6 FB
WELD 1 DET 4B
15 45°
32 19
WELD 2 TYP DET 4B
32 19
5 25x6 FB 4 OFF
6 25x6 FB 4 OFF
910

IL SECTION

NOTES:-
1) ALL SHARP EDGES AND BURRS TO BE REMOVED
2 DIMENSIONS ON WELDS REFER TO LEG LENGTH
3) FABRICATOR TO PROVIDE SATISFACTORY PROOF PRIOR TO STARTING FABRICATION THAT THE WELDING PROCEDURE ADOPTED WILL PROVIDE FOR A MINIMUM 'V' NOTCH CHARPY VALUE OF 27.1 JOULES (2.77 kgm - 20 ft lb) AT -30C IN BOTH THE DEPOSITED WELD METAL AND HEAT AFFECTED ZONE.

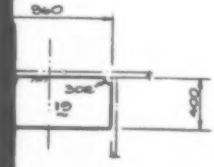

1230
33 19
470
500

DETAIL

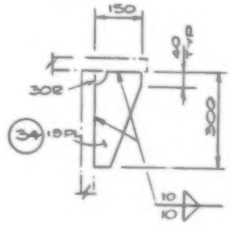

150x12 FB
30
30R
60°
6 6
6 6
1800

IJ DETAIL

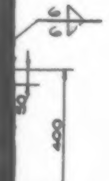
STEEL WEIGHT = 10.5 TONNES

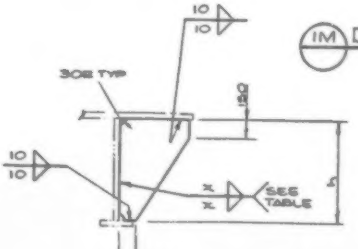

860
30R
19
400

DETAIL


150
20 TYP
30R
34 19 PL
300
10 10

IM DETAIL




10 10
30R TYP
120
10 10
x x SEE TABLE
h
130

h	x
< 1000	10
>1000 < 1200	8
>1200	6

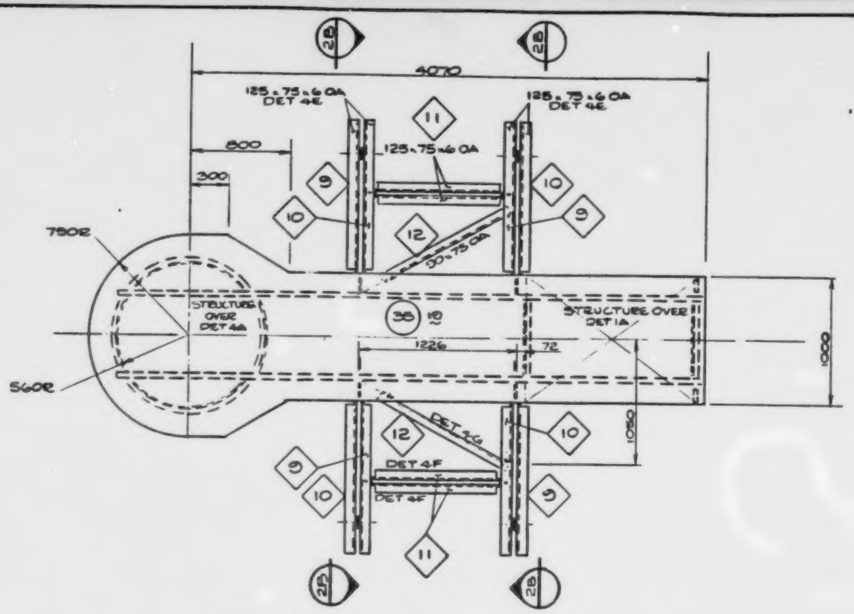
IH DETAIL

Rev	Date	Description	By	Chkd	App
C	8/3/88	PENETRATION WELDS MOD° TO FILLET TO EASE FABRICATION STIFF° ARRG^T ON REACTION PL MOD°	iD		
B	19/2/88	PL THICKNESS CHANGED 40PL/ITEM REACTION PLATE & PROPELLER HOLDING ARRANGEMENT MODIFIED	iD		
A	5/2/88	ORIGINAL ISSUE	–	–	–

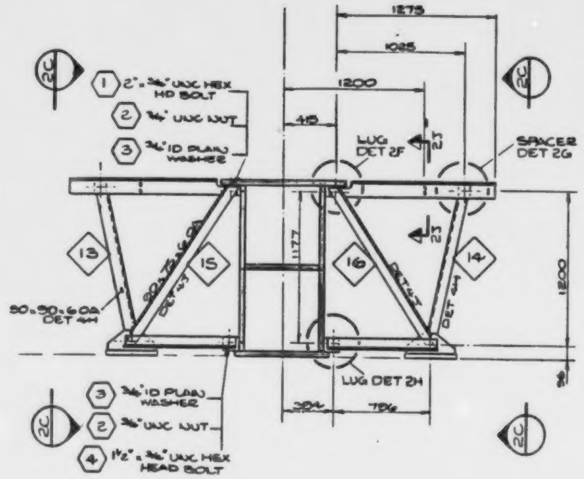
By Design inc
3024 Hampton Cres SW
Calgary Alberta T3E 4R2
☎ (403) 246 8949

Client: GEOTECHNICAL RESOURCES LTD
Project: FULL SCALE PROPELLER BLADE TESTING
Title: PROPELLER BLADE REACTION FRAME
ELEVATIONS & SECTIONS

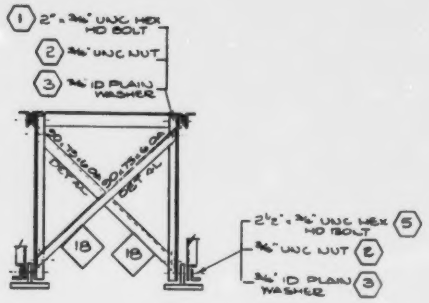
Scale: 1:25 & AS SHOWN
Drawn: CHRIS STANLEY
Checked:
Approved:
Date: FEB 5 88
Contr Dwg No:
Dwg No: 9448
Sheet: 1 OF 4
Rev: C


2B
2B
4070
125 × 75 × 6 OA
DET 4E
125 × 75 × 6 OA
DET 4E
11
125 × 75 × 6 OA
800
300
9
10
10
9
12
90 × 75 OA
750R
560R
STRUCTURE OVER DET 4A
38
19
STRUCTURE OVER DET 1A
1226
72
1000
12
DET 4G
10
1050
9
DET 4F
10
DET 4F
9
11
2B
2B

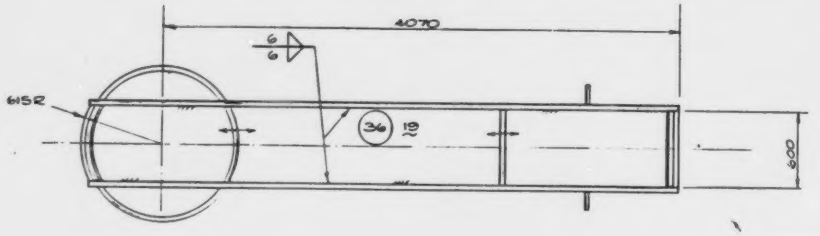
2A PLAN: MAIN GIRDER TOP FLANGE


2C
1 2" × 3/4" UNC HEX HD BOLT
2 3/4" UNC NUT
3 3/4" ID PLAIN WASHER
1275
1025
1200
415
LUG DET 2F
23
SPACER DET 2G
2C
13
90 × 90 × 6 OA DET 4H
DET 4J
15
1177
16
DET 4J
23
14
DET 4H
1000
1200
LUG DET 2H
304
796
3 3/4" ID PLAIN WASHER
2 3/4" UNC NUT
4 1 1/2" × 3/4" UNC HEX HEAD BOLT
2C
2C

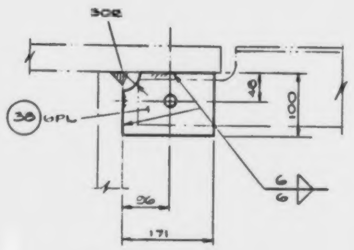
2B OUTRIGGER ARRANGEMENT


1 2" × 3/4" UNC HEX HD BOLT
2 3/4" UNC NUT
3 3/4" ID PLAIN WASHER
90 × 75 × 6 OA DET 4L
90 × 75 × 6 OA DET 4L
18
18
2 1/2" × 3/4" UNC HEX HD BOLT 5
3/4" UNC NUT 2
3/4" ID PLAIN WASHER 3

2C ELEVATION OF OUTRIGGER

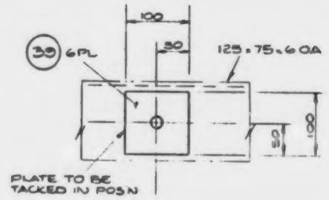

4070
6
6
615R
36
19
600

2D SECTION THRU GIRDER


30R
38 6PL
40
100
6
6
36
171

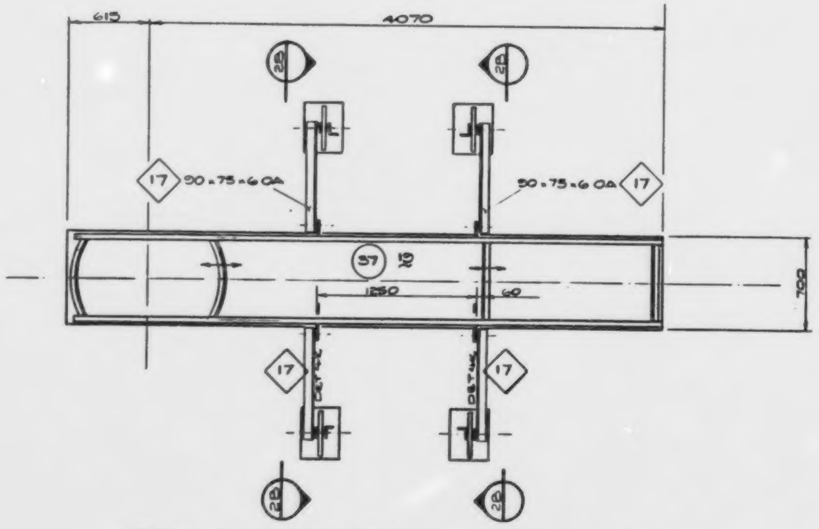
2F DETAIL

SCALE 1:5

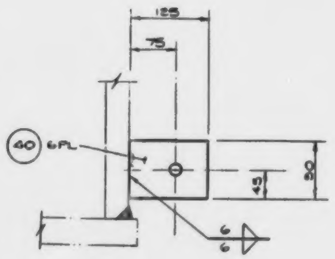

100
30
39 6PL
125 × 75 × 6 OA
50
100
PLATE TO BE TACKED IN POSN

2G DETAIL

SCALE 1:5

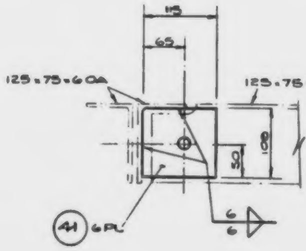

615
4070
2B
2B
17 90 × 75 × 6 OA
90 × 75 × 6 OA 17
37
16
1250
60
700
17
DET 4K
DET 4K
17
2B
2B

2E PLAN: MAIN GIRDER BOTTOM FLANGE


125
75
40 6PL
45
90
6
6

2H DETAIL

SCALE 1:5


115
65
125 × 75 × 6 OA
125 × 75 × 6 OA
108
30
41 6PL
6
6

2J DETAIL

SCALE 1:5

Rev	Date	Description	By	Chkd	App
B	19/2/88	PL THICKNESS CHANGED 40PL/19PL REACTION PLATE & PROPELLER HOLDING ARRANGEMENT MODIFIED	Ø		
A	5/2/88	ORIGINAL ISSUE	—	—	—

By Design inc
3024 Hampton Cres SW
Calgary Alberta T3E 4R2
☎ (403) 246 8949

Client: GEOTECHNICAL RESOURCES LTD

Project: FULL SCALE PROPELLER BLADE TESTING

Title: PROPELLER BLADE REACTION FRAME PLANS & OUTRIGGER DETAILS

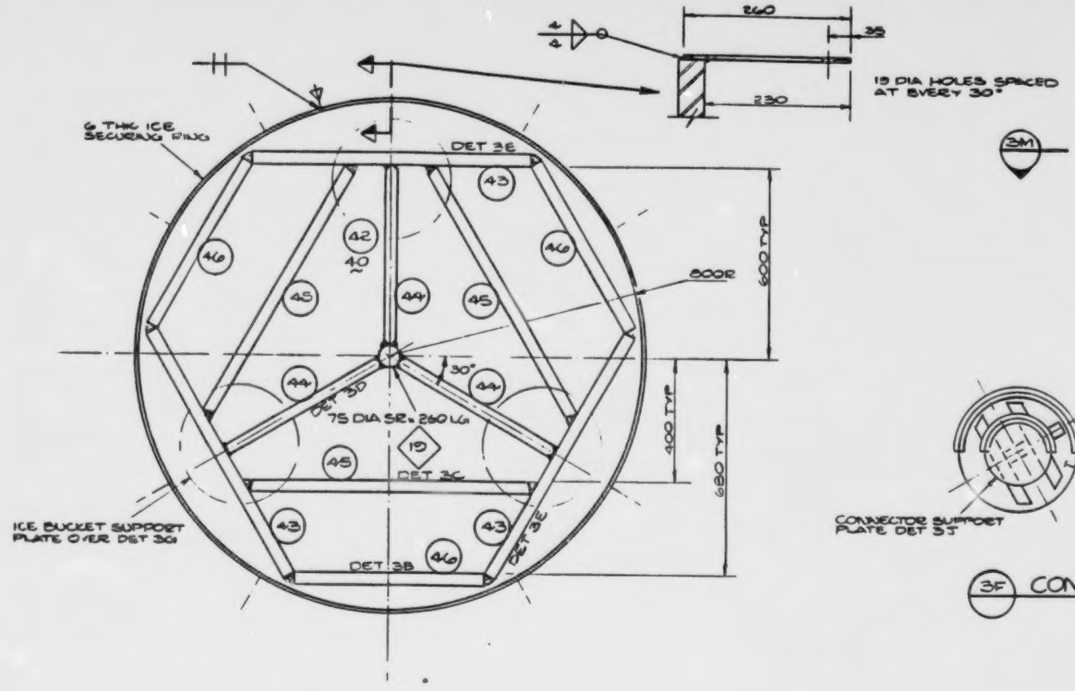
Scale: 1:25 & AS SHOWN	Drawn: CHRIS STANLEY
	Checked:
Date: FEB 5, 88	Approved:

Contr Dwg No:

Dwg No: 2

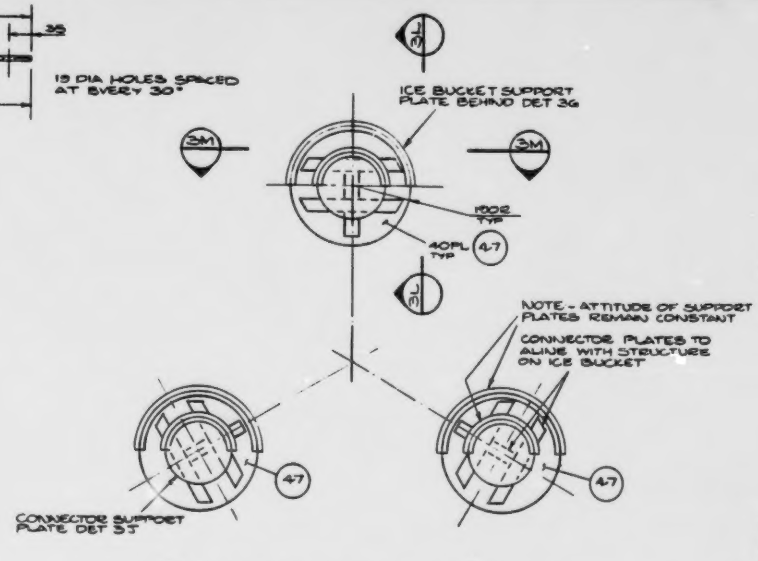
Sheet: 2 of 4

Rev: B



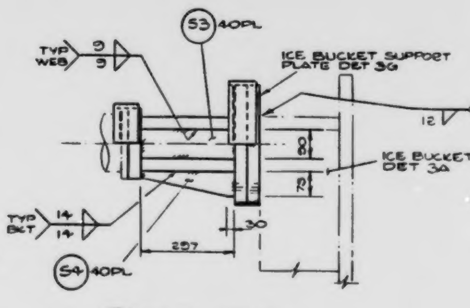
260
35
230
4
4
19 DIA HOLES SPACED AT EVERY 30°
6 THK ICE SECURING RING
DET 3E
43
42
40
46
45
44
800R
600 TYP
30°
DET 3D
75 DIA SR. 260 LG
19
DET 3C
400 TYP
680 TYP
ICE BUCKET SUPPORT PLATE OVER DET 3G
DET 3B
DET 3E

3A ICE BUCKET



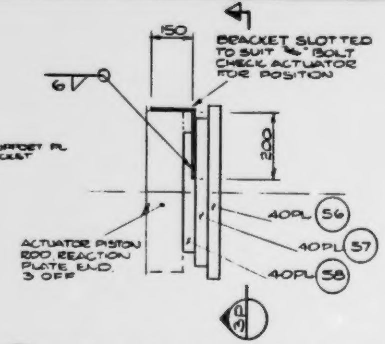
3L
ICE BUCKET SUPPORT PLATE BEHIND DET 3G
3M
3M
190R TYP
40PL TYP
47
3L
NOTE - ATTITUDE OF SUPPORT PLATES REMAIN CONSTANT
CONNECTOR PLATES TO ALINE WITH STRUCTURE ON ICE BUCKET
CONNECTOR SUPPORT PLATE DET 3J
47
47

3F CONNECTOR PLATE ARRG'T



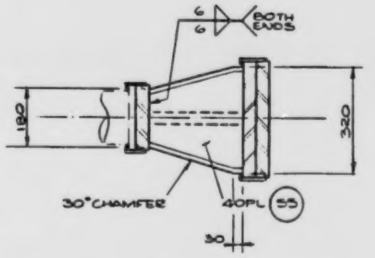
53 40PL
TYP WEB 9 9
ICE BUCKET SUPPORT PLATE DET 3G
12
TYP SUPPORT PL TO BUCKET
ICE BUCKET DET 3A
TYP BKT 14 14
257
30
54 40PL

3L ELEVATION



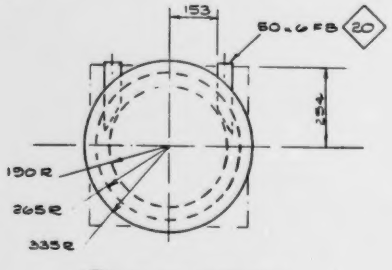
150
BRACKET SLOTTED TO SUIT ¾" BOLT CHECK ACTUATOR FOR POSITION
6
200
ACTUATOR PISTON ROD REACTION PLATE END 3 OFF
40PL 56
40PL 57
40PL 58
3P

3N BACK CONNECTOR PLATE



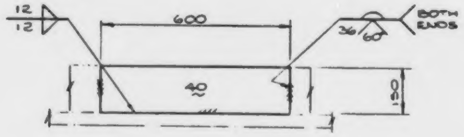
6 6 BOTH ENDS
180
320
30° CHAMFER
40PL 55
30

3M PLAN



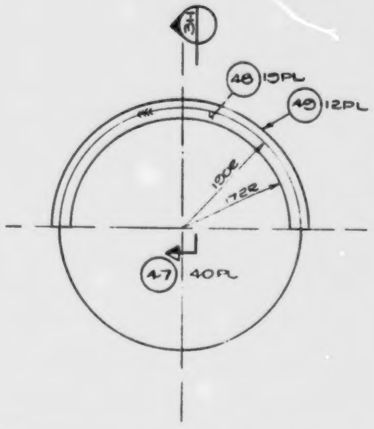
153
50 x 6 FB 20
254
190 R
265 R
335 R

3P ELEVATION



12 12
600
36 60° BOTH ENDS
40
150

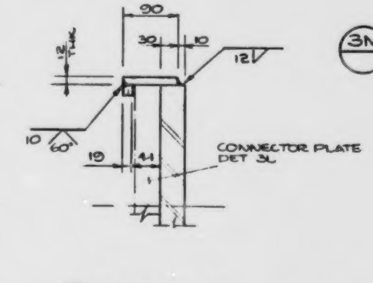
3B ITEM 46



3H
48 19PL
49 12PL
190R
172R
47 40PL

3G ICE BUCKET SUPPORT PLATE

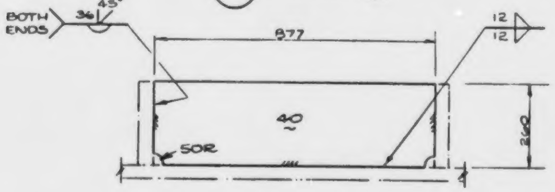
SCALE 1:5



90
30
10
12
12 THK
10 60°
19
41
CONNECTOR PLATE DET 3L

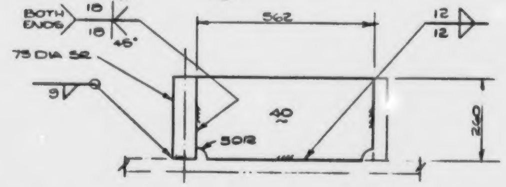
3H SECTION

SCALE 1:5



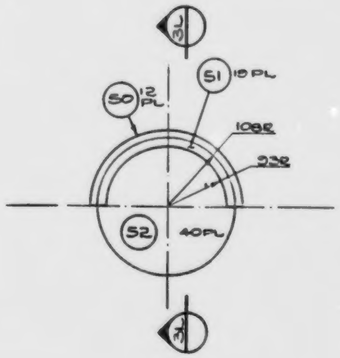
BOTH ENDS 36 45°
877
12 12
40
50R
260

3C ITEM 45



BOTH ENDS 18 18 45° 45°
562
12 12
75 DIA SR
9
40
50R
260

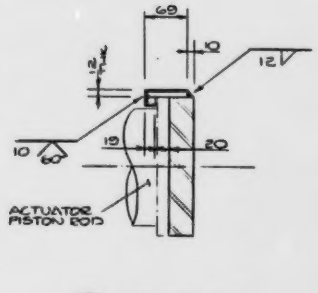
3D ITEM 44



3L
50 12 PL
51 19PL
108R
93R
52 40PL
3L

3J CONNECTOR SUPPORT PLATE

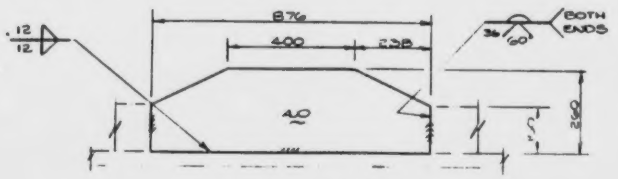
SCALE 1:5



69
10
12
12 THK
10 60°
19
20
ACTUATOR PISTON ROD

3K SECTION

SCALE 1:5



12 12
876
400
238
36 60° BOTH ENDS
40
260

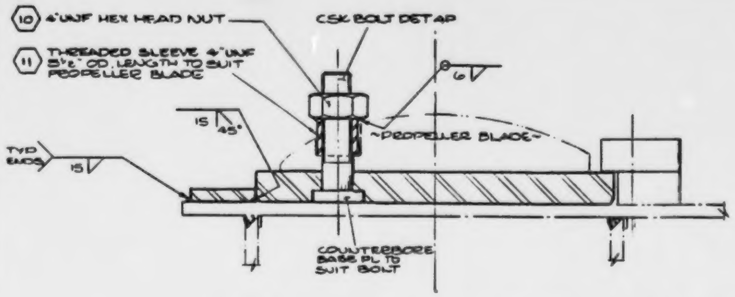
3E ITEM 43

Rev	Date	Description	By	Chkd	App
B	8/3/88	SIZE OF BACK CONNECTOR PL INCREASED			
A	5/2/88	ORIGINAL ISSUE	–	–	–

By Design inc
3024 Hampton Cres SW
Calgary Alberta T3E 4R2
(403) 246 8548

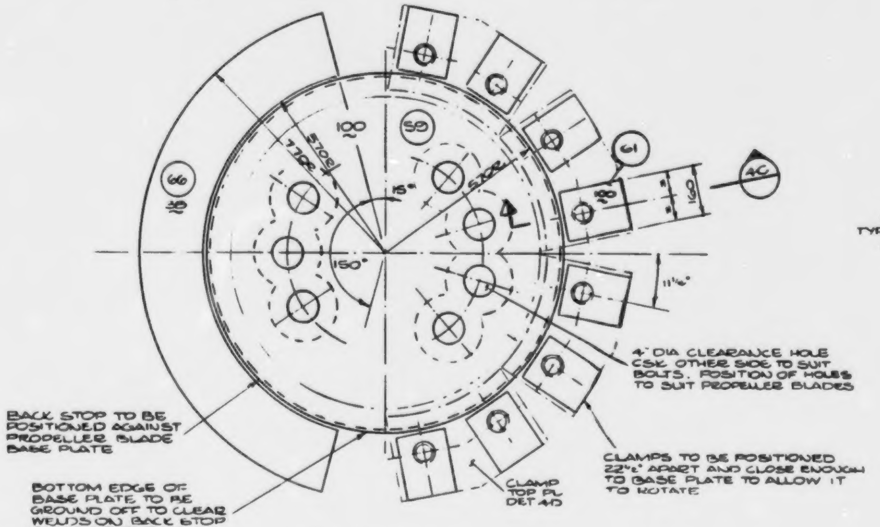
Client GEOTECHNICAL RESOURCES LTD
Project FULL SCALE PROPELLER BLADE TESTING
Title PROPELLER BLADE REACTION FRAME
ICE BUCKET & CONNECTOR PLATE DETAILS

Scale 1:10
Drawn CHRIS STANLEY
Checked
Approved
Date FEB 5 87
Contr Dwg No
Dwg No
Sheet 2 OF 4
Rev B



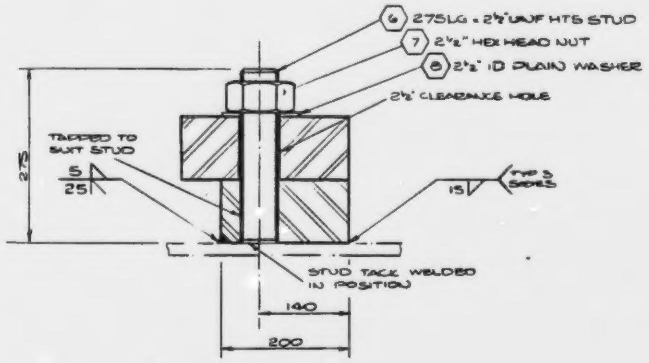
(10) 4" UNF HEX HEAD NUT
CSK BOLT DET 4P
(11) THREADED SLEEVE 4" UNF 5½" OD. LENGTH TO SUIT PROPELLER BLADE
6
15
45°
TYP ENDS
15
~PROPELLER BLADE~
COUNTERBORE BASE PL TO SUIT BOLT

4A PROPELLER SUPPORT STRUCTURE



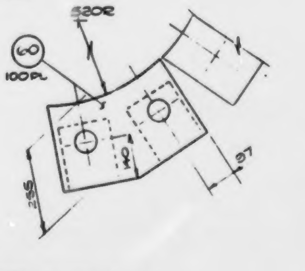
66
38
100
59
61
4C
15°
150°
160
4" DIA CLEARANCE HOLE CSK. OTHER SIDE TO SUIT BOLTS. POSITION OF HOLES TO SUIT PROPELLER BLADES
BACK STOP TO BE POSITIONED AGAINST PROPELLER BLADE BASE PLATE
BOTTOM EDGE OF BASE PLATE TO BE GROUND OFF TO CLEAR WELDS ON BACK STOP & CLAMP BLOCKS
CLAMP TOP PL DET 4D
CLAMPS TO BE POSITIONED 22½° APART AND CLOSE ENOUGH TO BASE PLATE TO ALLOW IT TO ROTATE

4B PLAN



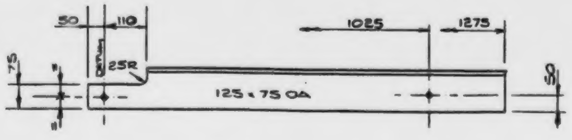
(6) 275LG × 2½" UNF HTS STUD
(7) 2½" HEX HEAD NUT
(8) 2½" ID PLAIN WASHER
2½" CLEARANCE HOLE
TAPPED TO SUIT STUD
5
25
275
15
TYP 3 SIDES
STUD TACK WELDED IN POSITION
140
200

4C DETAIL



320R
60
100PL
40
37
255

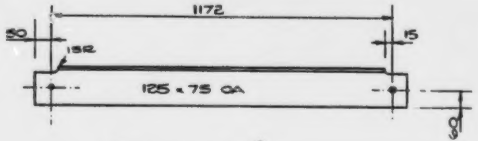
4D DETAIL



50
110
1025
1275
25R
125 × 75 OA
75
50

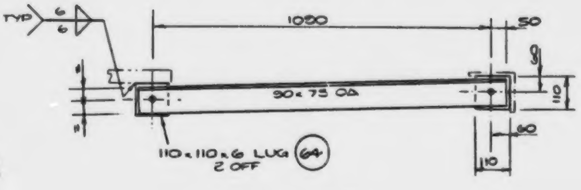
4E ITEM 10

ITEM 5 OPPOSITE



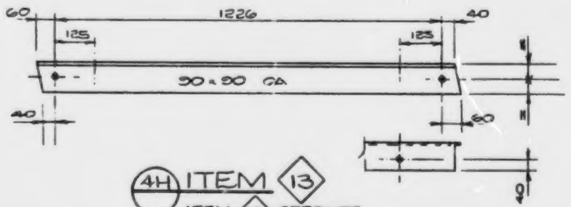
1172
50
15
15R
125 × 75 OA
50

4F ITEM 11



TYP 6 6
1050
50
90 × 75 OA
110
60
110
110 × 110 × 6 LUG (64) 2 OFF

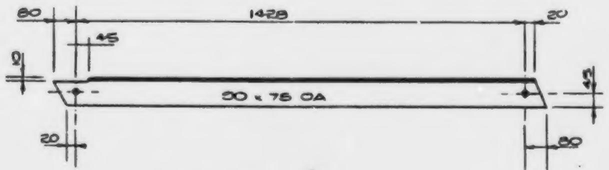
4G ITEM 12



60
1226
40
125
125
90 × 90 OA
40
60
40

4H ITEM 13

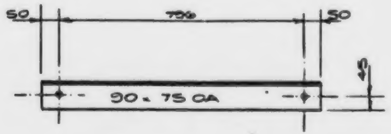
ITEM 14 OPPOSITE



80
1428
20
45
90 × 75 OA
20
80
45

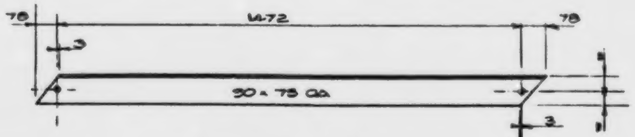
4J ITEM 15

ITEM 16 OPPOSITE



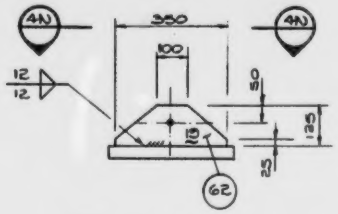
50
756
50
90 × 75 OA
45

4K ITEM 17



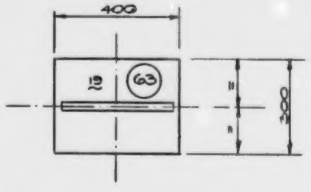
78
1472
78
3
90 × 75 OA
3

4L ITEM 18



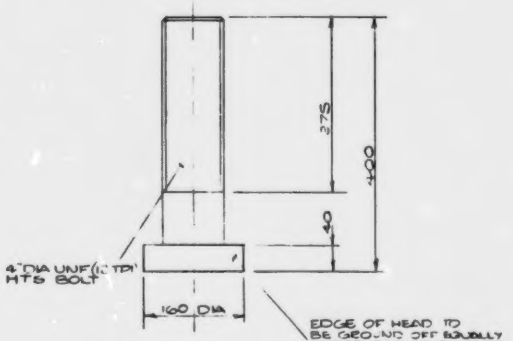
4N
350
4N
100
12
12
50
15
135
25
62

4M DETAIL



400
12
63
200

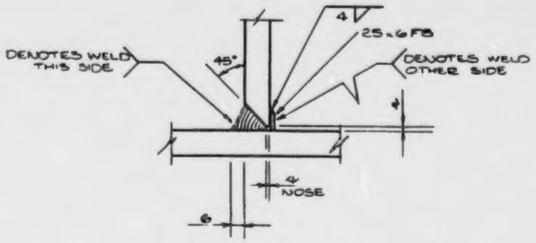
4N PLAN



275
400
40
4" DIA UNF (12 TPI) HTS BOLT
160 DIA
EDGE OF HEAD TO BE GROUND OFF EQUALLY WHERE TWO BOLT HEADS OVERLAP

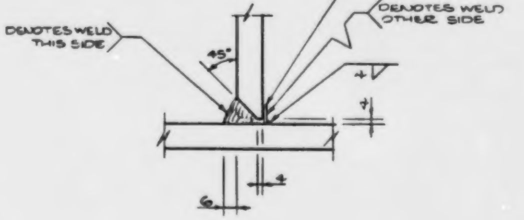
4P ITEM 9

SCALE 1:5



DENOTES WELD THIS SIDE
45°
4
25 × 6 FB
DENOTES WELD OTHER SIDE
4 NOSE
6

4R WELD '1'



25 × 6 FB
DENOTES WELD THIS SIDE
DENOTES WELD OTHER SIDE
45°
4
4
6

4S WELD '2'

Rev	Date	Description	By	Chkd	App
C	8/3/88	CLAMP TOP PLATE & PROPELLER SECURING BOLT MODIFIED	A		
B	19/2/88	PL THICKNESS CHANGED 40PL/19PL REACTION PLATE & PROPELLER HOLDING ARRANGEMENT MODIFIED	a		
A	5/2/88	ORIGINAL ISSUE	–	–	–

by Design inc
3024 Hampton Cres SW
Calgary Alberta T3E 4R2
☎ (403) 246 8949

Client GEOTECHNICAL RESOURCES LTD

Project FULL SCALE PROPELLER BLADE TESTING

Title
PROPELLER BLADE REACTION FRAME
PROPELLER BLADE SUPPORT STRUCTURE
& DETAILS

Scale 1:10 & AS SHOWN

Drawn CHRIS STANLEY

Checked

Date FEB 5: 87

Approved

Contr Dwg No

Dwg No

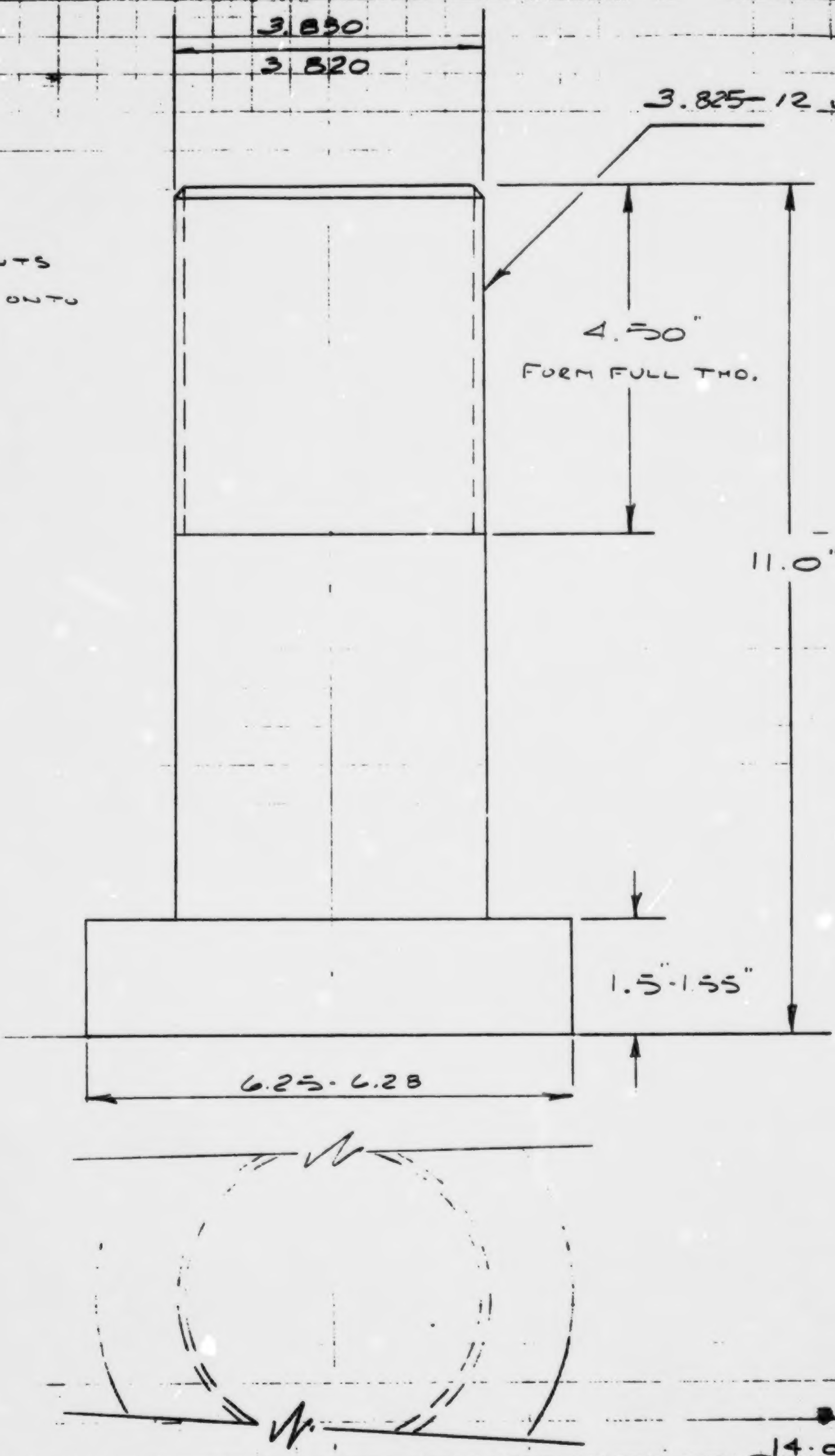
Sheet 4 OF 4

Rev C

ATERIAL
4140

CHECK ALL NUTS
FIT FREELY ONTO
ALL BOLTS

QTY 7


3.830
3.820
3.825-12 UN
4.50"
FORM FULL THD.
11.0"
1.5"-1.55"
6.25-6.28

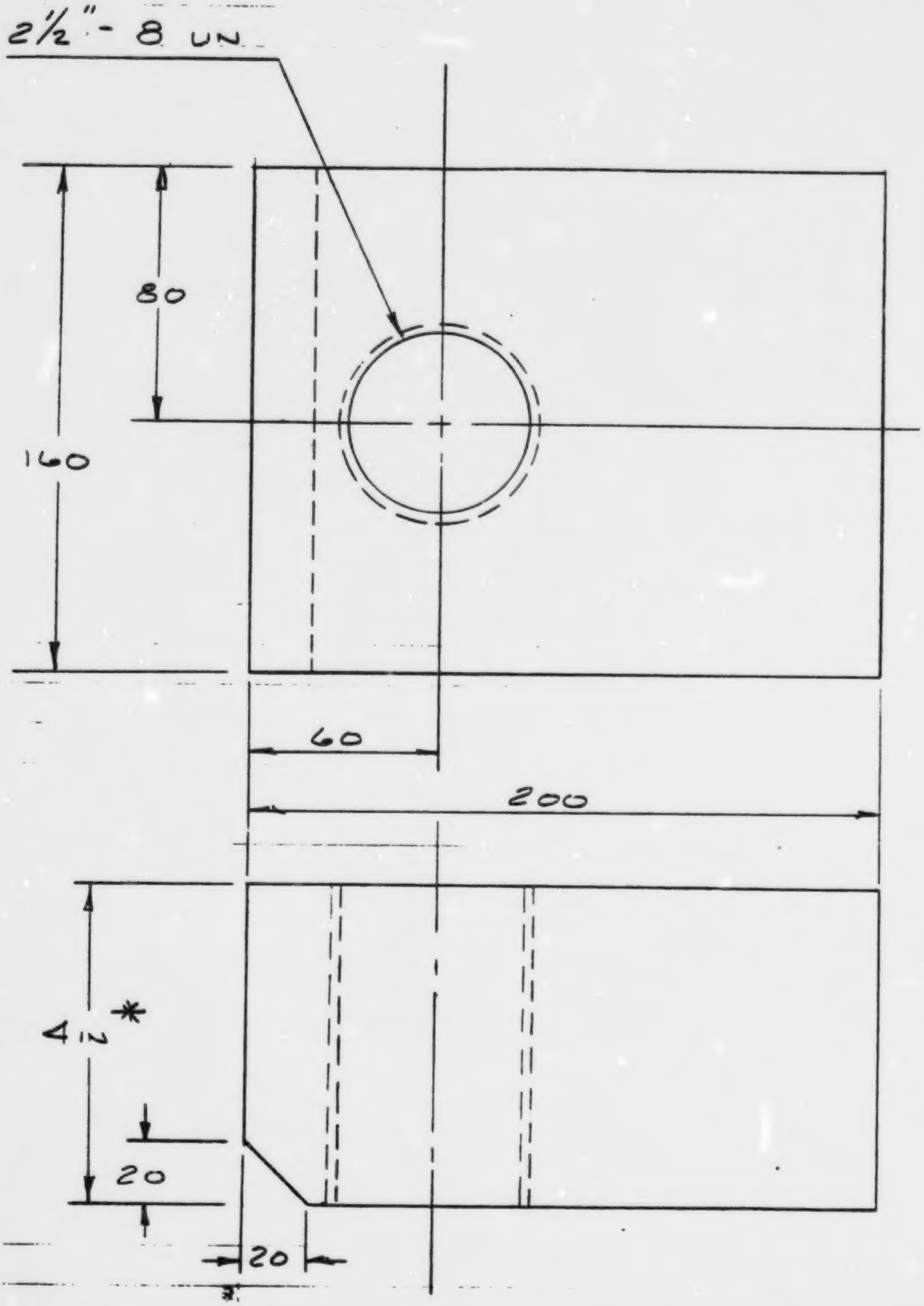
14.03.88
GEOTECH
BP

9 [illegible] B [illegible] 4 [illegible] 12 UN

FOR ADRIC[illegible] 15 MARCH 88

MATERIAL - 4" MS PLATE - TO BE THE SAME THICKNESS AS ITEM 59

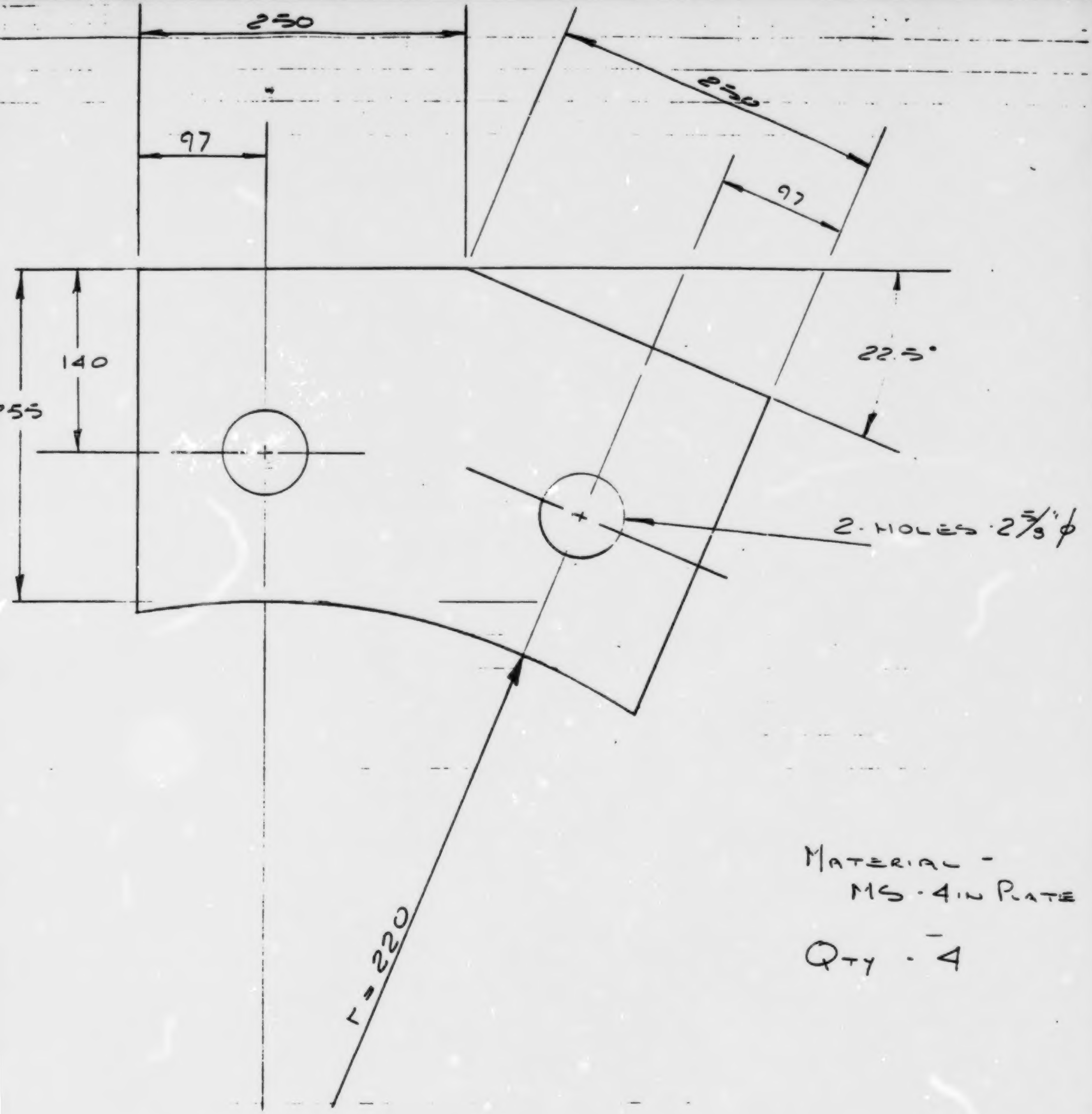
QTY - 8


2½" - 8 UN
80
160
60
200
4 IN *
20
20

61 CLAMP SECURING PLATE

14-03-1

GEOTECH


250
97
250
97
140
55
22.5°
2 · HOLES · 2⅝" ϕ
r = 220

MATERIAL –
MS · 4 IN PLATE

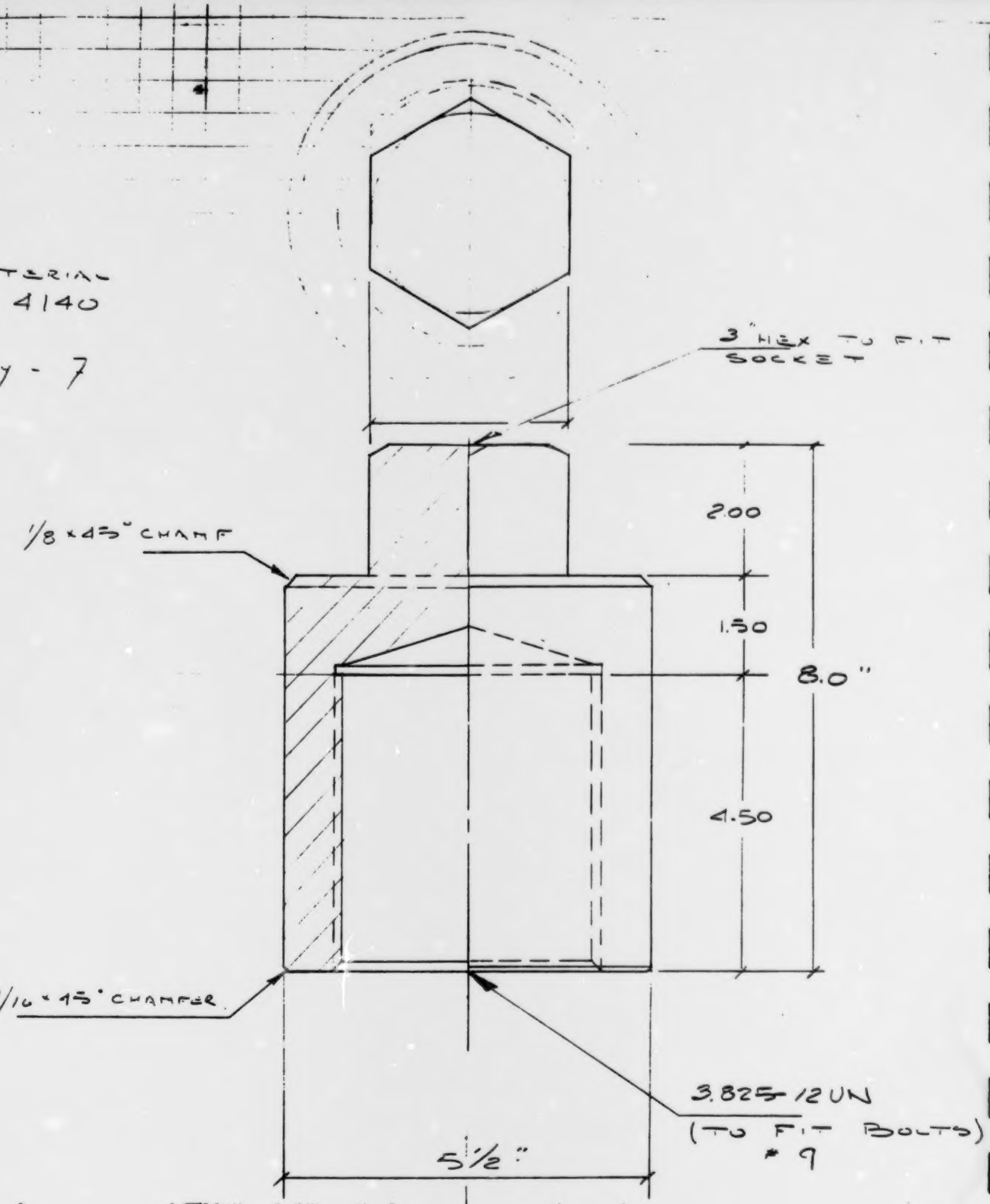
QTY · 4

60 · CLAMP · PROPELLER BLADE

14-03-89

MATERIAL
4140

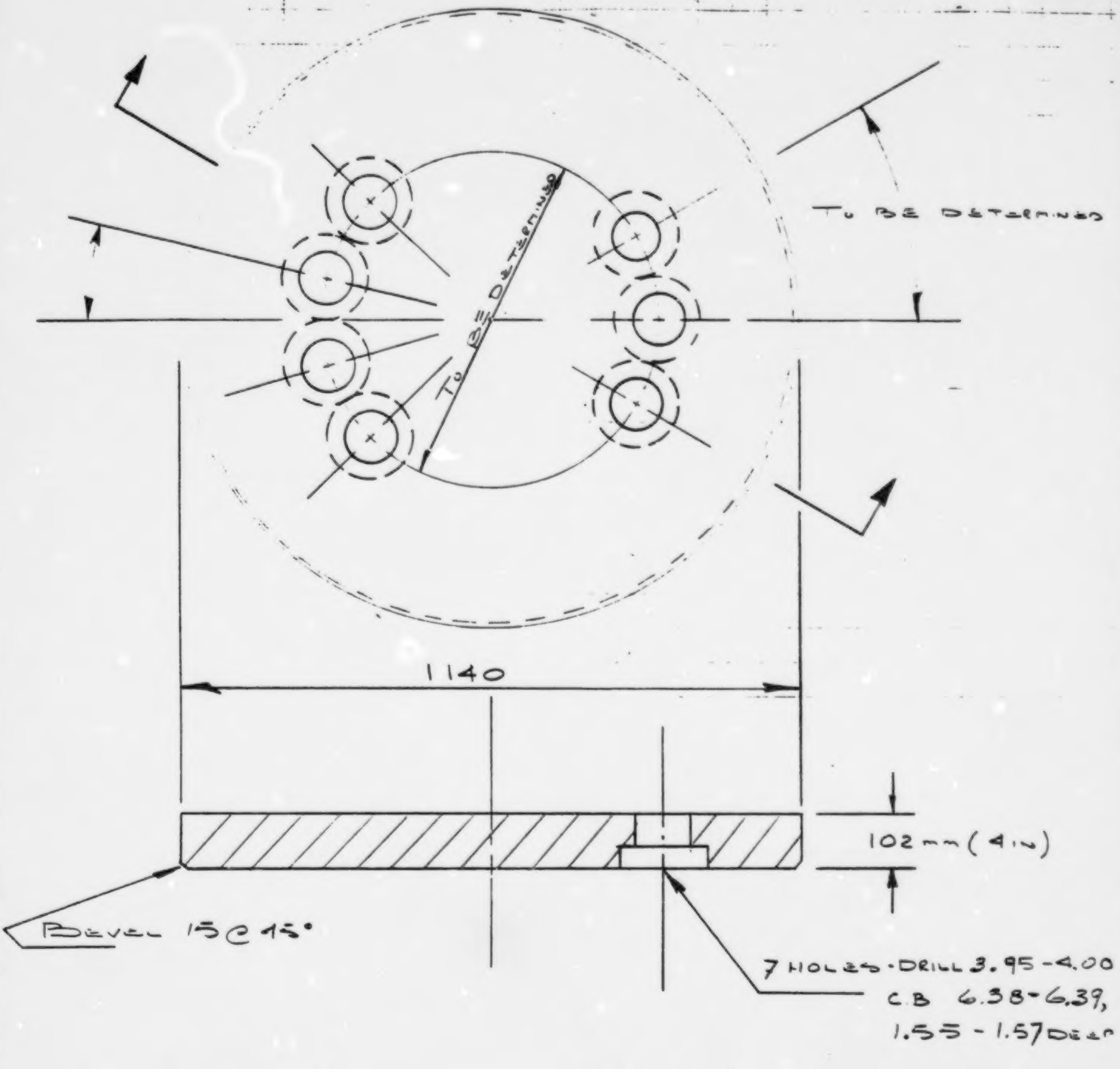
QTY - 7


3" HEX TO FIT SOCKET
1/8 × 45° CHAMF
2.00
1.50
8.0"
4.50
1/16 × 45° CHAMFER
3.825-12 UN (TO FIT BOLTS) # 9
5½"

10 NUT - 4" - 12 UN

14.03.88
GEOTECH

MATERIAL · MS · 4 IN PLATE
QTY - 1


TO BE DETERMINED
TO BE DETERMINED
1140
102 mm (4 in)
BEVEL 15 @ 15°

7 HOLES · DRILL 3.95 - 4.00
C.B 6.38 - 6.39,
1.55 - 1.57 DEEP

59 PROPELLER SECURING PLATE

14-03-1988
GIBOTECH

[redacted]

Rev	Date	Description	By	Chkd	Appd
B	17/2/88	Rev to suit drawings	CJ		
C	8/3/88	REV TO SUIT DRGS	CJ		

MATERIAL LIST

PROPELLER BLADE REACTION FRAME

Drawing No. 88001A

by Design inc

3024 Hampton Cres SW
Calgary Alberta T3E 4R2
☎ (403) 248 8948

Client: Geotechnical Resources Ltd
Project: Full Scale Propeller
Blade Testing.
Date: February 5th, 1988

PLATES ( )

SHT 1 OF 6

PART N°	N° OFF	DESCRIPTION	MATERIAL	GRADE	SUPPLIER	REMARKS	LOC
1	1	MAIN GIRDER WEB	19PL	300W			1A
2	2	SUPPORT PLATE	↓	↓			1A 1D
3	1	REACTION PLATE WEB	↓	↓			1A
4	1	↓	↓	↓			↓
5	1	↓	↓	↓			1D
6	1	↓	↓	↓			↓
7	1	MAIN GIRDER WEB	↓	↓			↓
8	1	REACTION PLATE	↓	↓			1B
9	2	GIRDER SUPPORT PLATE	↓	↓			↓
10		—					
11	2	REACTION PL BRACKET	19PL	300W			1B
12		—					
13	1	REACTION PL BRACKET	19PL	300W			1B
14		—					
15	1	REACTION PL BRACKET	19PL	300W			1B
16		—					
17	1	REACTION PL BRACKET	19PL	300W			1B
18		—					
19	1	REACTION PL BRACKET	19PL	300W			1B
20		—					
21	1	REACTION PL BRACKET	19PL	300W			1B
22		—					
23		—					
24		—					
25	1	REACTION PL BRACKET	19PL	300W			1B
26	5	↓	↓	↓			↓
27	1	↓	↓	↓			↓
28	2	REACTION PLATE FLANGE	↓	↓			1C
29	1	↓	↓	↓			↓

PLATES ○

SHT 2 OF 6

PART N°	N° OFF	DESCRIPTION	MATERIAL	GRADE	SUPPLIER	REMARKS	LOC
30	2	GIRDER END PLATES	19PL	300W			
31	2	GIRDER SUPPORT PLATES					1C
32	2	GIRDER END PLATES					1K
33	1	REACTION TOP PLATE					1L
34	2	BRACKET					1E
35	1	GIRDER TOP FLANGE					1M
36	1	GIRDER STIFFENER					2A
37	1	GIRDER BOTTOM FLANGE	↓				2D
38	4	LUG	6PL				2E
39	4	SPACER					2F
40	4	LUG					2G
41	4	↓	↓				2H
42	1	ICE BUCKET PLATE	40PL				2J
43	3	ICE BUCKET STIFFENER					3A
44	3						
45	3						
46	3	↓ ↓ ↓					
47	6	CONNECTOR END PLATE	↓				↓
48	3	CONNECTOR SECURING RING	19PL				3F/3G
49	3		12PL				3G
50	3		↓				↓
51	3	↓ ↓ ↓	19PL				3J
52	3	CONNECTOR END PLATE	40PL				
53	3	CONNECTOR WEB					↓
54	6	CONNECTOR FLANGE					3L
55	3	CONNECTOR BRACKET					
56	3	BACK CONNECTOR PLATE					↓
57	3						3N
58		↓ ↓ ↓	↓	↓			↓

PLATES ( )

SHT 3 OF 6

PART N°	N° OFF	DESCRIPTION	MATERIAL	GRADE	SUPPLIER	REMARKS	LOC
59	1	PROPELLER SECURING PL	100 PL	300W			4B
60	4	PROPELLER BLADE CLAMP	↓	↓			4D
61	8	CLAMP SECURING PL	↓				4B
62	4	BEARING PAD WEB	19PL				4M
63	4	BEARING PAD	19PL				4N
64	4	LUG	6PL				4G
65	1	ICE SECURING RING	6PL				3A
66	1	BACK STOP	38PL	↓			4B
67							
68							
69							
70							
71							
72							
73							
74							
75							
76							
77							
78							
79							
80							
81							
82							
83							
84							
85							
86							
87							

SECTIONS ◇

SHT 4 OF 6

PART Nº	Nº OFF	DESCRIPTION	MATERIAL	GRADE	SUPPLIER	REMARKS	LOC
1	2	GIRDER WEB STIFFENER	1800 × 150 × 12 FB	300W			1A, 1D
2	2	WELD 1 BACKING BAR	1200 × 25 × 6 FB	↓			↓
3	1	↓	580 × 25 × 6 FB	↓			1B
4	6	↓	597 × 25 × 6 FB	↓			1B, 1C
5	8	WELD 2 BACKING BAR	577 × 25 × 6 FB	↓			1C, 1L
6	6	WELD 1/2 BACKING BAR	315 × 25 × 6 FB	↓			1K, 1L
7	2	WELD 1 BACKING BAR	405 × 25 × 6 FB	↓			1L
8							
9	4	OUTRIGGER STRUCTURE	1325 × 125 × 75 × 6 OA	300W			2A
10	4	↓	1325 × 125 × 75 × 6 OA	↓			↓
11	4	↓	1272 × 125 × 75 × 6 OA	↓			↓
12	2	↓	1190 × 90 × 75 × 6 OA	↓			↓
13	2	↓	1346 × 90 × 90 × 6 OA	↓			2B
14	2	↓	1346 × 90 × 90 × 6 OA	↓			↓
15	2	↓	1588 × 90 × 75 × 6 OA	↓			↓
16	2	↓	1588 × 90 × 75 × 6 OA	↓			↓
17	4	↓	875 × 90 × 75 × 6 OA	↓			2E
18	4	↓	1628 × 90 × 75 × 6 OA	↓			2C
19	1	ICE BUCKET CENTRE	260 × 75 DIA SR	↓			3A
20	2	CONNECTOR PLATE STRAPS	350 × 50 × 6 FB	↓			3P
21	1	REACTION FRAME WEB STIF	600 × 100 × 12 FB	↓			1D
22	1	↓	720 × 100 × 12 FB	↓			↓
23	1	↓	840 × 100 × 12 FB	↓			↓
24	1	↓	960 × 100 × 12 FB	↓			↓
25	1	↓	1050 × 100 × 12 FB	↓			↓
26	1	↓	1120 × 100 × 12 FB	↓			↓
27	1	↓	1200 × 100 × 12 FB	↓			↓
28							
29							

SECTIONS ◇

SHT 5 OF 6

PART N°	N° OFF	DESCRIPTION	MATERIAL	GRADE	SUPPLIER	REMARKS	LOC
30							
31							
32							
33							
34							
35							
36							
37							
38							
39							
40							
41							
42							
43							
44							
45							
46							
47							
48							
49							
50							
51							
52							
53							
54							
55							
56							
57							
58							

HARDWARE ⬡

SHT 6 OF 6

PART Nº	Nº OFF	DESCRIPTION	MATERIAL	GRADE	SUPPLIER	REMARKS	LOC
1	8	2" x 3/4" UNC HEX HEAD BOLT		A325			2B 2C
2	16	3/4" UNC NUT		MS			
3	32	3/4" ID PLAIN WASHER		MS			↓
4	4	1 1/2" x 3/4" UNC HEX HEAD BOLT		A325			2B
5	4	2 1/2" x 3/4" UNC HEX HEAD BOLT		↓			2C
6	8	11" x 2 1/2" UNF STUD		HTS 4140			4C
7	8	2 1/2" UNF NUT		MS			
8	8	2 1/2" ID PLAIN WASHER		MS			↓
9	7	16" x 4" UNF CSK HD BOLT		HTS 4140			4P
10	7	4" UNF HEAD NUT		MS			4A
11	7	4" UNF SLEEVE	5 1/2" OD x 7" LG	MS			4A
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							

APPENDIX A.2

Non Destructive Testing on Propeller Blade

2.0 NON-DESTRUCTIVE TESTING OF THE BLADES

After receipt of the propeller blade in Calgary a set of non-destructive tests were carried out on the blade. The purpose of the tests were to identify any large cracks or voids in the blade. The tests consisted of dye penetrant testing and ultrasonic testing. The work was carried out by Hoogensen Metallurgical Ltd., Calgary, and is described in their report.

The most significant find was the existence of a crack system in the root of the blade. Although significant, it was not sufficient severe to invalidate the blade as a suitable test vehicle. The major reason being that the propeller blade would be oriented in such a way so that the crack system would be on the compression side of the blade.

Hoogensen
Metallurgical
Engineering Ltd.

5632 Burbank Road S.E.
Calgary, Alberta
Canada T2H 1Z4
Telephone: (403) 258-1555
Telex: 03-821172 CGY
Fax: (403) 229-2788

Chris P Hoogensen, Dipl Eng P Eng
Robert M Thom M Sc P Eng
Robert L Sutherby M Sc P Eng

March 14th, 1988

No. 8803-1899

Geotech Engineering
4500 - 5th Avenue N.E.
Calgary, Alberta
T2E 7C3

ATTENTION: DR. PAUL SPENCER

Dear Sir:

As requested, we have performed a liquid penetrant and ultrasonic inspection of a large propeller blade removed from the Kigoriak icebreaker. At the time of this examination, the blade was situated in a storage area at your Calgary location.

The blade bore the following markings:

Lloyds Rot 210 /611-51
AJ 4310 CUNIAL
02 - 08 - 76 G.W. 2676 KG

RECOND BY LIPS NV CANADA INC
24 - 06 -82
MWB $

The inspection of this piece was performed on March 3rd and 4th, 1988. Figure 1 shows the results of the liquid penetrant inspection (LPI) of one side of the blade. The observed defects were found to consist of small surface pores and have been indicated by circling them with a black felt marker. In the upper right hand corner of this picture, a small edge crack was also noted. This appears to be associated with the plastic deformation seen at this edge of the blade.

Figure 2 shows the results of the LPI of the other side of the component. As can be seen, the number and density of the pore surface defects is much greater on this face. These pores are limited to the inside face of the blade. Also shown in Figure 2, and in greater detail in Figure 3, is a pair of cracks located at the base of the blade near the hub bolt area. The upper short crack was measured to be 100 mm long, while the lower more extensive crack was 250 mm long. Both of these cracks appeared quite jagged along their length indicating them to consist of cracks which have initiated at different areas and eventually coalesced into a single crack.

In order to obtain an indication of the extent of this cracking, a Krautkramer flaw depth indicator was used on the 250 mm crack. The results of this testing are shown in Figure 4 and confirms the presence of three (3) crack fronts along this defect. The deepest area of this crack has been determined to be 80 mm and as expected, the cracks appear to have a semi-elliptical shape.

To determine the presence of subsurface defects, this blade was also inspected using an ultrasonic technique. Using a Krautkramer-Branson USK 6 ultrasonic unit in conjunction with a 2.25 MHZ compression wave probe, the entire surface of the blade (with the exception of the lower underside of the hub) was examined. The cast nature of the blade material limited this inspection to the first three (3) inches of depth due to the strong attenuation of the applied signals. Since only a compressive wave source was being utilized, any observed indications would be limited to three dimensional defects or free surfaces parallel with the blade surface.

The results of this ultrasonic inspection found no significant defects to be present in the areas examined. An attempt was also made to use a lower frequency shear wave probe for the detection of defects normal to the surface. This technique, however, proved to be unsuccessful since the resulting signal had excessive noise. This is considered to be a result of the coarse nature of the cast material.

Should you have any questions with respect to the work which we have performed for you, or require further assistance, please do not hesitate to contact me.

Yours very truly,

HOOGENSEN METALLURGICAL ENGINEERING LTD.

Robert M. Thom

Robert Thom

Robert M. Thom, M.Sc., P. Eng.

RMT/kh

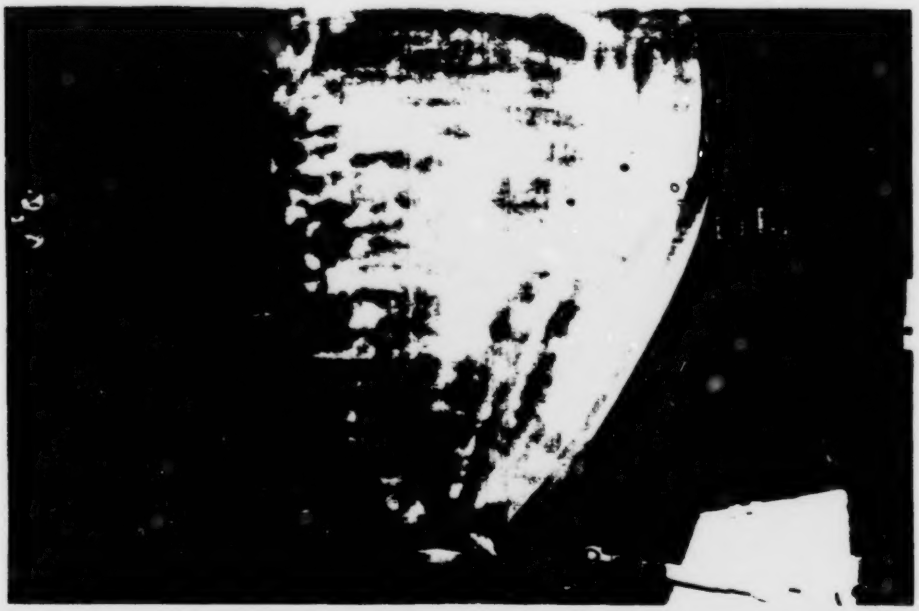


Figure 1

LPI of One Side of Blade

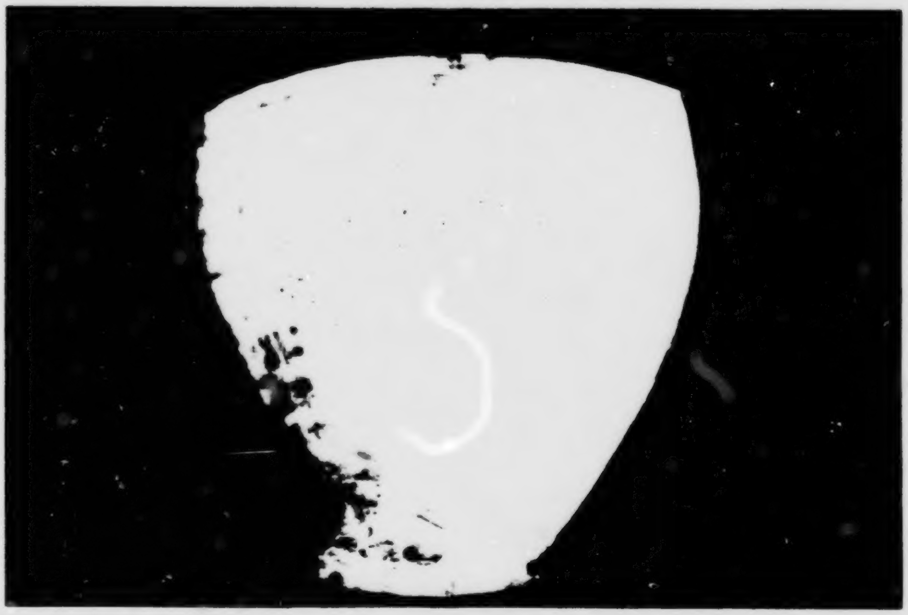


Figure 2

LPI of Other Side of Blade

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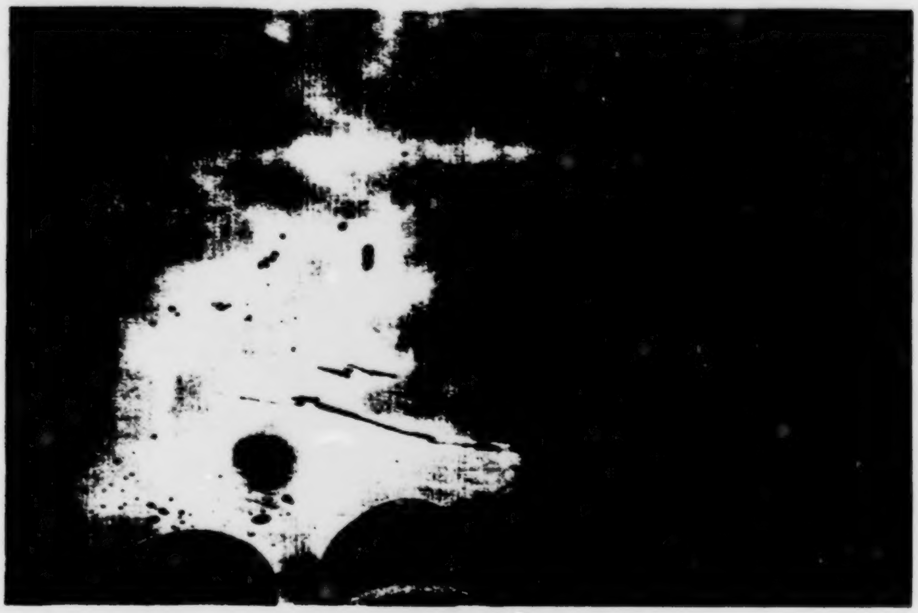

Figure 3

Close-Up of Crack Near Hub Area

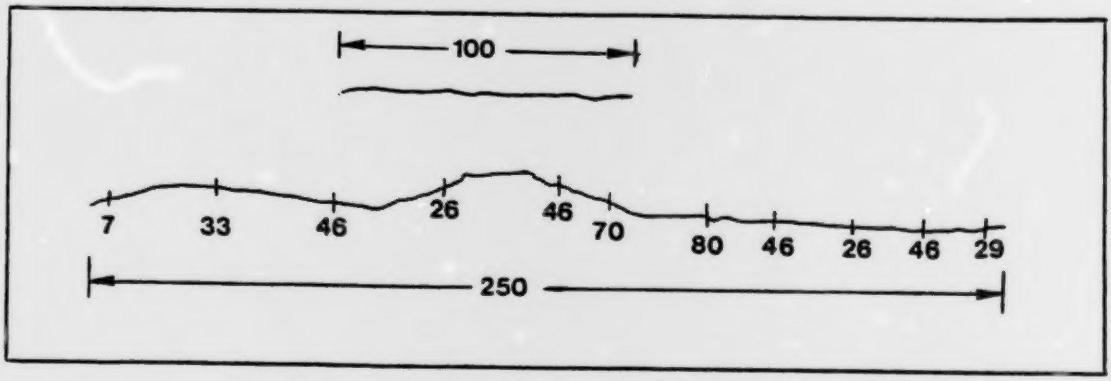
100
7
33
46
26
46
70
80
46
26
46
29
250

Figure 4

Indicated Crack Depths

Hoogensen
Metallurgical
Engineering Ltd.

Chris P. Hoogensen, Dipl.Eng. P.Eng
Robert M. Thom, M.Sc. P.Eng
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Canada T2H 1Z4
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Telex: 03-821172 CGY
Fax: (403) 229-2788

March 17th, 1988 No. 8803-1899

Geotech Engineering
4500 - 5th Avenue N.E.
Calgary, Alberta
T2E 7C3

ATTENTION: DR. PAUL SPENCER

Dear Sir:

As you requested in our conversation today, we enclose the photograph negatives for our letter report dated March 14th, 1988. I have also spoken with Mr. Hoogensen with regard to the expected resolution of defects during our ultrasonic examination of the propeller blade. Normally, the resolution is limited to one (1) wavelength of the probe being used. Since the probe used was 2.25 MHz, this would correspond to 1.6 mm.

The attenuation observed in the coarse blade material, however, makes such a high resolution doubtful, but a defect in the order of 5-10 mm should still be readily detected. This resolution, of course, would only apply to the projected area normal to the ultrasonic signal.

Should you have any additional questions, please feel free to call.

Yours very truly,

HOOGENSEN METALLURGICAL ENGINEERING LTD.

Robert Thom

Robert M. Thom, M.Sc., P. Eng.

RMT/kh

APPENDIX A.3

Overload Detector Schematics

3.0 OVERLOAD DETECTOR SCHEMATICS

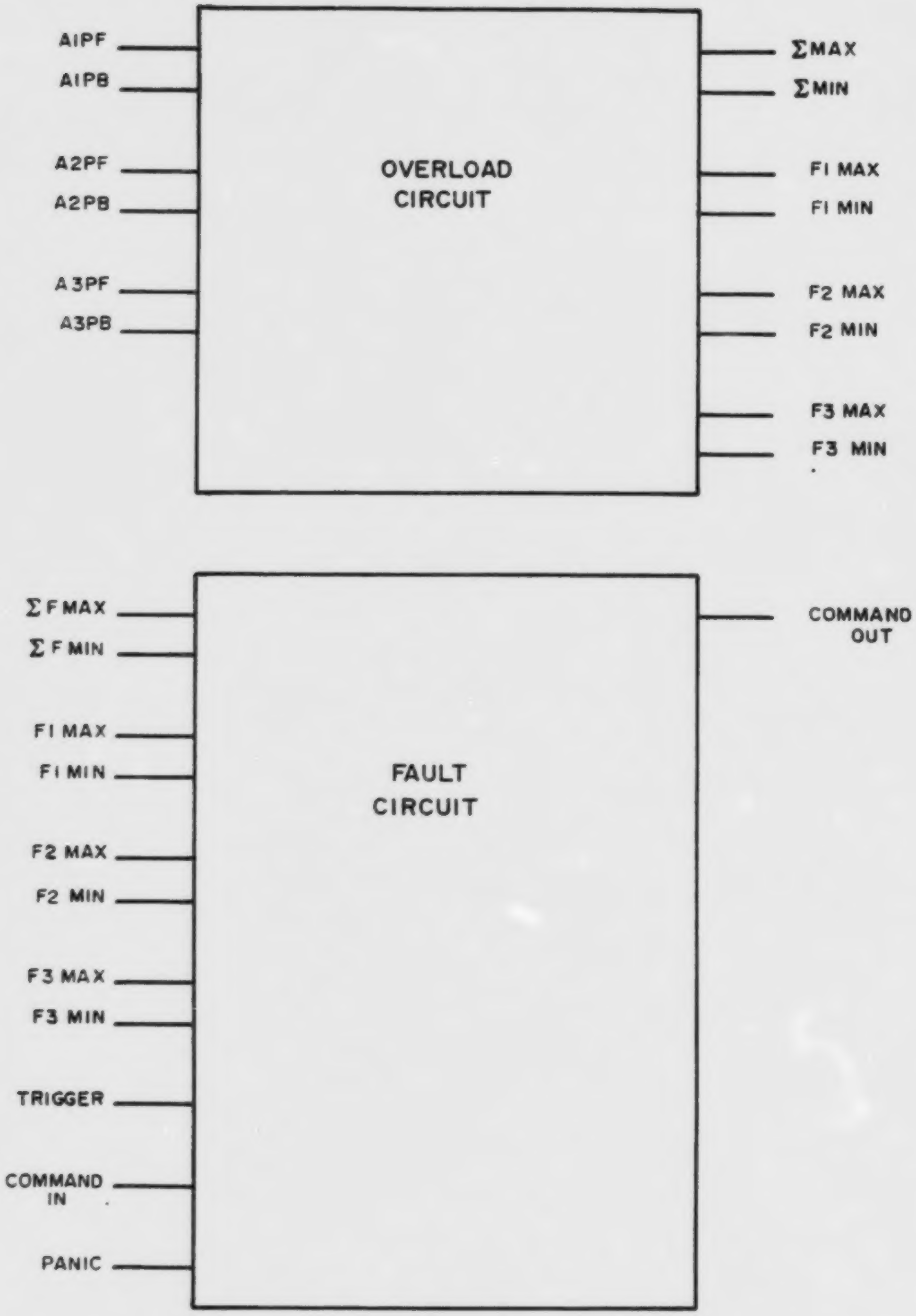
The function of the overload detector was to limit the applied loading to a safe level. This was partially important since the combined hydraulic capacity of the three actuators exceeded the capacity of the reaction frame by almost a factor of five.

Two overload conditions were designed for, the first being the total applied load greater than a critical the second was that any one of the actuators would provide a tensile rather than compressive stress.

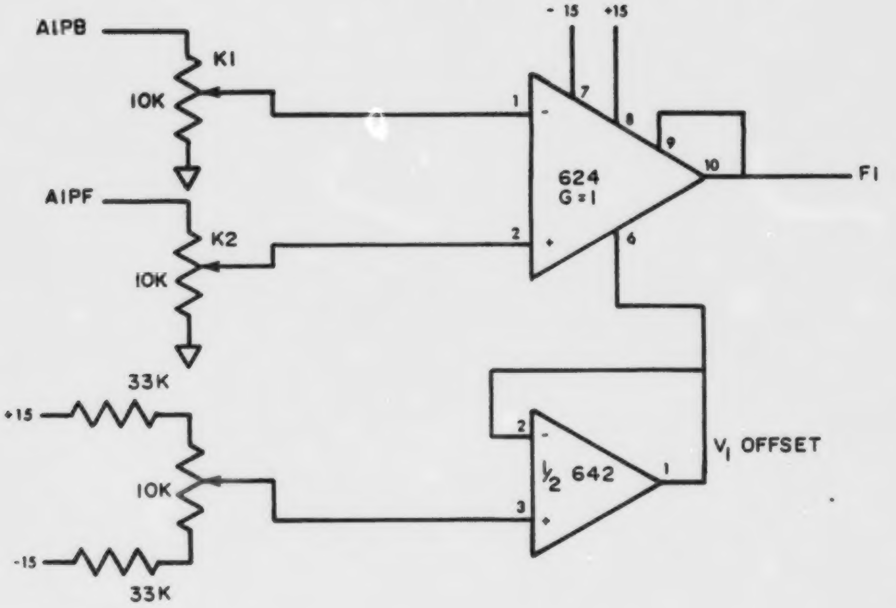
When an overload condition was detected a retraction of the ice bucket was initiated. This was accomplished by shorting, to ground the command input of the servo controllers.

The overload detector used analogue methods of signal inspection rather than digital because of that approaches inherent simplicity. It furthermore avoided additional complications associated with multi- tasking of high speed digital systems.

The overload detector was constructed using a 'bread board' approach because of the limited useful lifetime of the device and the relatively benign environment in which the device would be expected to work.


A1PF
A1PB
A2PF
A2PB
A3PF
A3PB
OVERLOAD CIRCUIT
ΣMAX
ΣMIN
F1 MAX
F1 MIN
F2 MAX
F2 MIN
F3 MAX
F3 MIN
ΣF MAX
ΣF MIN
F1 MAX
F1 MIN
F2 MAX
F2 MIN
F3 MAX
F3 MIN
TRIGGER
COMMAND IN
PANIC
FAULT CIRCUIT
COMMAND OUT

OVERLOAD PROTECTION CIRCUIT


A1PB
K1
10K
A1PF
K2
10K
33K
+15
10K
-15
33K
- 15
+15
1
2
7
8
9
10
6
624
G = 1
F1
2
3
1
½ 642
V1 OFFSET

$$F1 = K_2\ A1PF - K_1\ A1PB + V_1 OFFSET$$

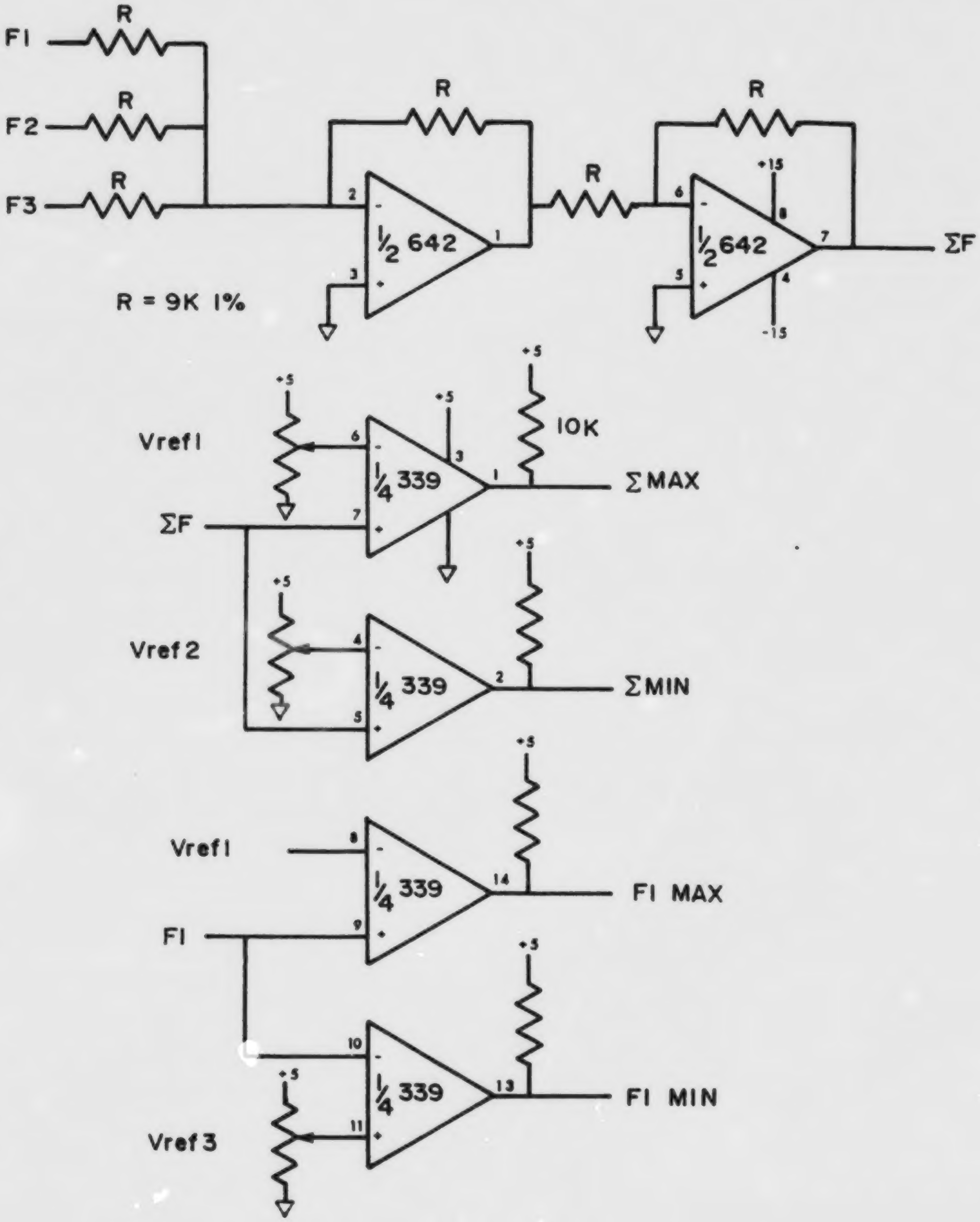
NOTES:

1. SAME CIRCUIT FOR A2PF AND A2PB, AND A3PF AND A3PB

2. A1PF AND A1PB ARE THE PRESSURE TRANSDUCER OUTPUT OUTPUT VOLTAGES CORRESPONDING TO THE FRONT AND BACK OF THE ACTUATOR PISTON WHERE THE FRONT PRESSURE YIELDS POSITIVE LOAD AND THE BACK PRESSURE YIELDS NEGATIVE LOAD.

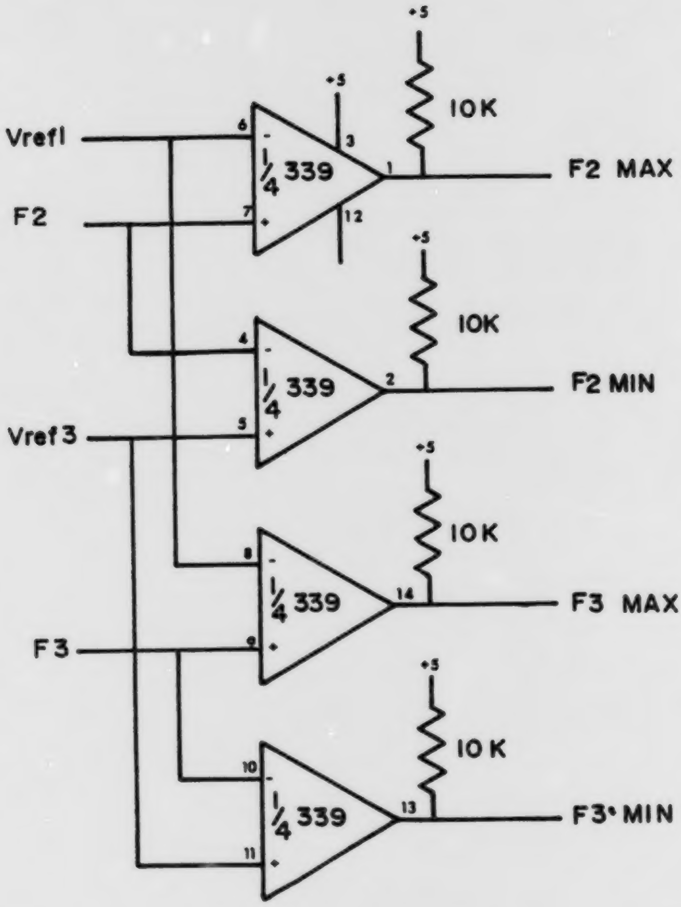
3. K_1 AND K_2 ARE ADJUSTED TO CORRESPOND TO THE AREA OF THE BACK AND FRONT OF THE ACTUATOR PISTON TIMES THE SCALE FACTOR FOR THE DESIRED ENGINEERING UNITS. ($K_1 = .519$, $K_2 = .909$)

OVERLOAD CIRCUIT


F1
F2
F3
R
R
R
R
R
R
R = 9K 1%
1/2 642
1/2 642
2
3
1
6
5
7
8
4
+15
-15
ΣF
+5
Vref1
1/4 339
6
7
3
1
10K
ΣMAX
ΣF
Vref2
1/4 339
4
5
2
ΣMIN
Vref1
1/4 339
8
9
14
F1 MAX
F1
1/4 339
10
11
13
F1 MIN
Vref3

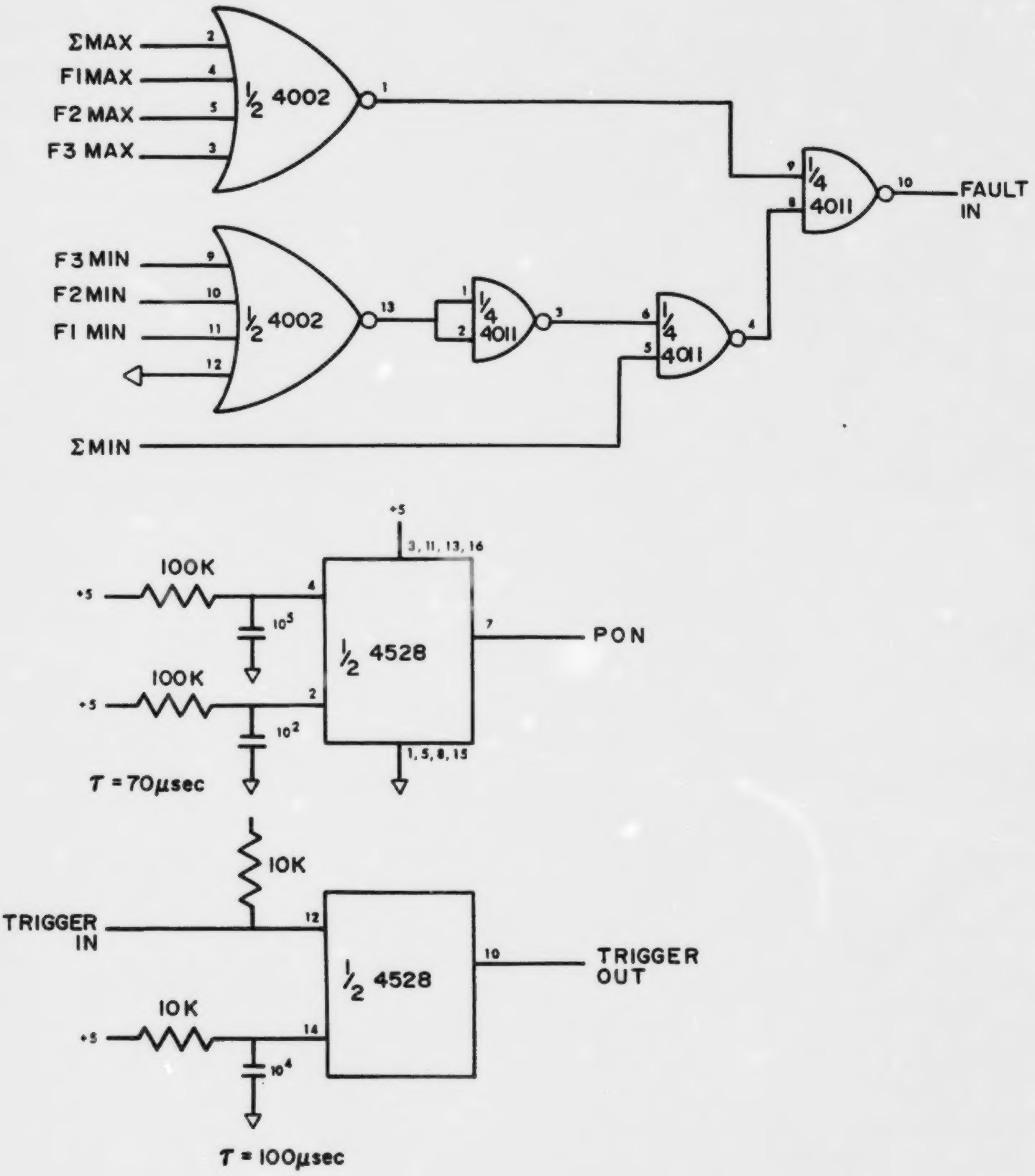
NOTES:
1. Vref1 IS SET TO THE MAXIMUM LOAD DESIRED
2. Vref2 IS SET TO THE MINIMUM LOAD THAT WILL SHEAR THE BOLTS HOLDING THE ICE BUCKET (.27 MEGA NEUTONS)
3. Vref3 IS SET TO ZERO

OVERLOAD CIRCUIT cont.

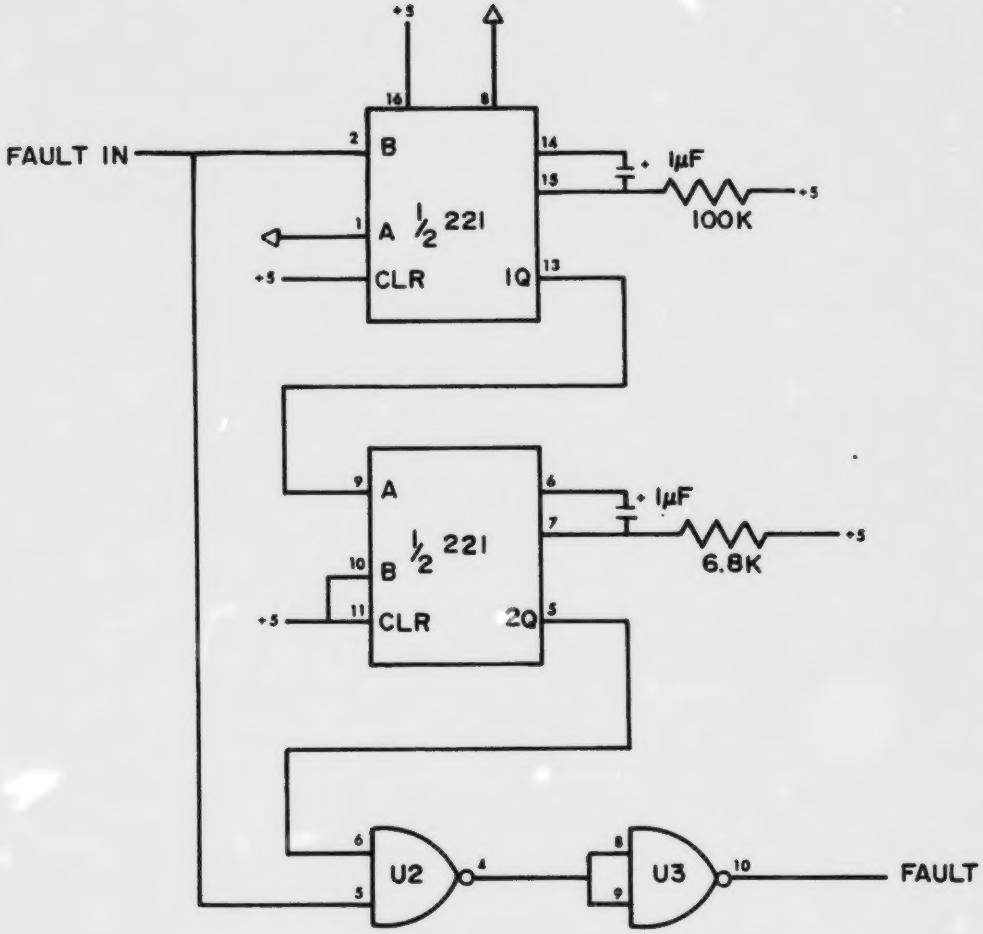


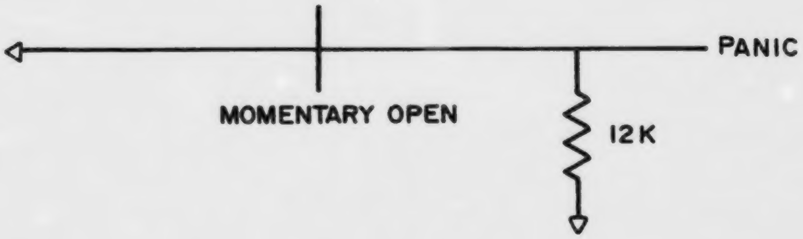
+5
+5
10K
Vref1
6
-
3
1/4 339
1
F2 MAX
F2
7
+
12
+5
10K
4
-
1/4 339
2
F2 MIN
Vref3
5
+
+5
10K
8
-
1/4 339
14
F3 MAX
F3
9
+
+5
10 K
10
-
1/4 339
13
F3* MIN
11
+

OVERLOAD CIRCUITS cont.

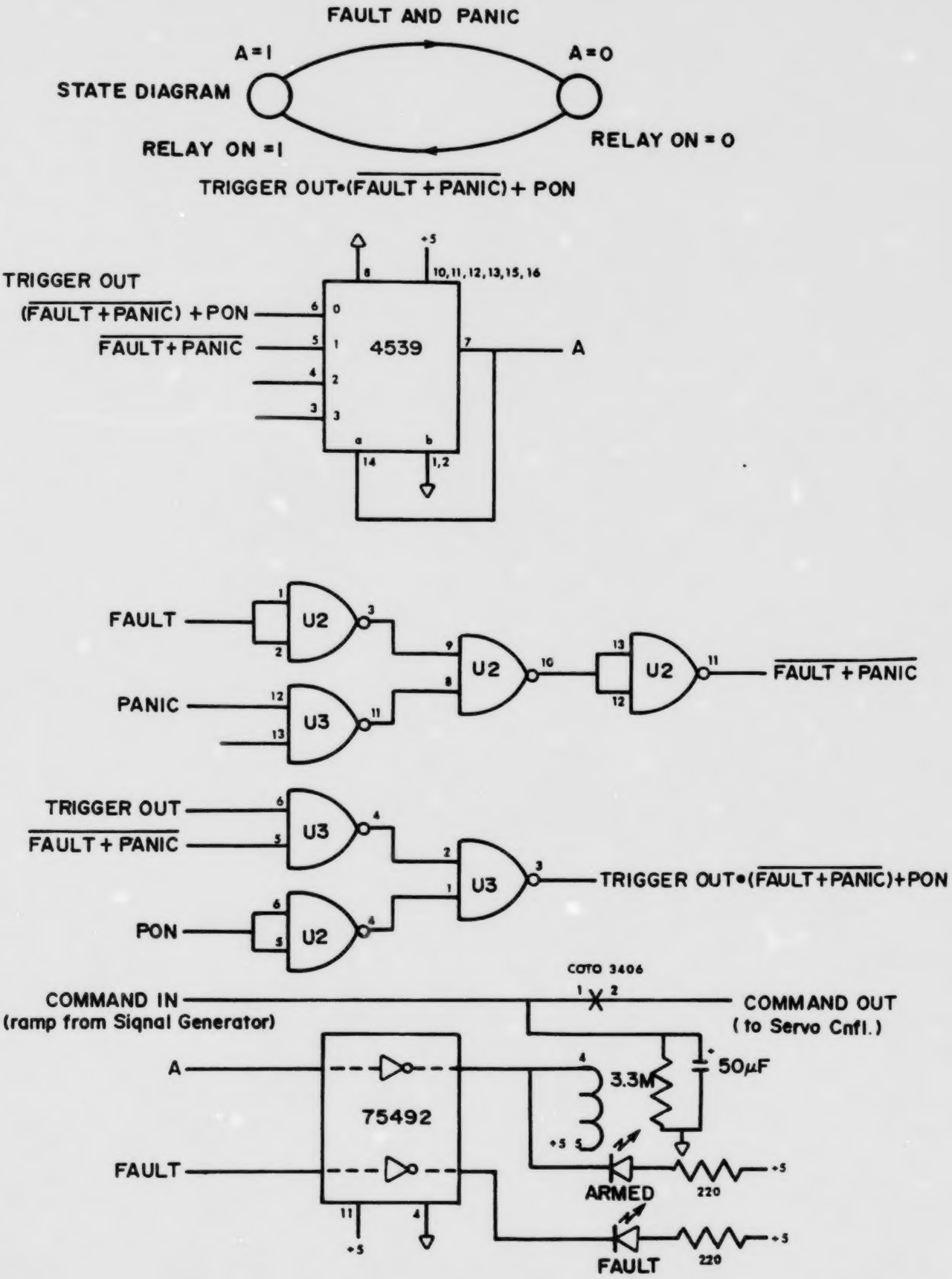

ΣMAX
F1MAX
F2 MAX
F3 MAX
2
4
5
3
½ 4002
1
9
8
¼ 4011
10
FAULT IN
F3 MIN
F2 MIN
F1 MIN
9
10
11
12
½ 4002
13
1
2
¼ 4011
3
6
5
¼ 4011
4
ΣMIN
+5
3, 11, 13, 16
100K
+5
4
10^5
½ 4528
7
PON
100K
+5
2
10^2
1, 5, 8, 15
τ = 70μsec
10K
TRIGGER IN
12
½ 4528
10
TRIGGER OUT
10K
+5
14
10^4
τ = 100μsec

FAULT CIRCUIT


+5
16
8
FAULT IN
2
B
14
1µF
15
100K
+5
1
A
1/2 221
+5
CLR
1Q
13
9
A
6
1µF
7
6.8K
+5
1/2 221
10
B
+5
11
CLR
2Q
5
6
U2
4
8
U3
10
FAULT
5
9


PANIC
MOMENTARY OPEN
12K

FAULT CIRCUIT cont.


FAULT AND PANIC
A=1
A=0
STATE DIAGRAM
RELAY ON =1
RELAY ON = 0
TRIGGER OUT•($\overline{\text{FAULT + PANIC}}$) + PON
+5
8
10,11,12,13,15,16
TRIGGER OUT
($\overline{\text{FAULT + PANIC}}$) + PON
6
0
$\overline{\text{FAULT+ PANIC}}$
5
1
4539
7
A
4
2
3
3
a
b
14
1,2
FAULT
1
U2
3
2
9
U2
10
13
U2
11
$\overline{\text{FAULT + PANIC}}$
12
8
PANIC
12
U3
11
13
TRIGGER OUT
6
U3
4
$\overline{\text{FAULT + PANIC}}$
5
2
U3
3
TRIGGER OUT•($\overline{\text{FAULT+PANIC}}$)+PON
1
6
PON
5
U2
4
COTO 3406
COMMAND IN
(ramp from Signal Generator)
1
2
COMMAND OUT
(to Servo Cntl.)
A
4
3.3M
50μF
75492
+5
5
FAULT
ARMED
220
+5
11
4
+5
FAULT
220
+5

FAULT CIRCUIT cont.

APPENDIX A.4

Software Listing

4.0 SOFTWARE LISTING

The software was designed to operate on a Hewlett Packard Series 310 computer with 3 Megabyte of installed RAM. The programmes were written in Hewlett Packard Basic Version 4.0.

Two major programmes were written "PROP_DAS" and "PROP_PLOT". The first programme is the data acquisition routine which controls the operation of the Waveform Generator and the operation of the two Infotek A/D subsystems. Assistance in the form of assembly language routine, was provided by Infotek to allow for the efficient use of two such A/D sub systems.

The design parameters for the data acquisition system were:

Number of Channels	32
Sampling Speed/Channel up to	5.0 kHz
Resolution	12 bit
Minimum Data Window	3.0s
Storage of Data on Floppy Disk	

The second major programme was "PROP_PLOT" which provided the capability to view and plot the data recorded by "PROP_DAS". The major attributes of the data plotting programme was the ability to present time series plots of any of the recorded channels. Provide cross plots between recorded channels or calculated quantities. At the time of data collected there was the ability to calculate the actuator load from the actuator oil pressure signals, to calculate the total applied load from the individual actuator loads and the calculation of principal strains from the rosette strain gauges applied to the blade surface. Various other utility functions are provided which included determination of the minimum and maximum of the various raw and calculated quantities.

Some smaller utility programmes were also written and these are "Test Purge" and "Disk_Copy" and "Test_Copy".

The programmes listed above consisted of approximately 8,500 lines of code with "PROP_PLOT" being the largest with 5,800 lines of code.

```
10!RE-STORE "Test_purge:,700,0"
20   !  ***************************************************************************
30   ! ¦                          -- TESTPURGE --                                  ¦
40   ! ¦                                                                          ¦
50   ! ¦Calling name: Test_purge                         Version: 2.0             ¦
60   ! ¦Programmer  : N Chalk                            Date    : 29 Feb 1988
70   ! ¦--------------------------------------------------------------------------¦
80   ! ¦Description: This programme purges files built by the multi-card AD-200¦
90   ! ¦data acquisition system from a specified disk.                            ¦
100  ! ¦ - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - ¦
110  ! ¦Root programme: TESTPURGE -- Version 1.0                                   ¦
120  ! ¦__________________________________________________________________________¦
130  ! ¦Modification history                                  ¦Date       ¦By
140  ! ¦------------------------------------------------------¦-----------¦-------¦
150  ! ¦ 1.                                                   ¦           ¦       ¦
160  ! ¦ 2.                                                   ¦           ¦       ¦
170  ! ¦ 3.                                                   ¦           ¦       ¦
180  !  * *************************************************************************
190   OPTION BASE 1
200   COM /Index/ Index$[25],Index_desc$[80]
210   COM /Header/ Test_hdr$(99)[10],Test_time(99),INTEGER Test_status(99)
220   COM /String/ Time$[8],Date$[12],Status$[2]
230   COM /Files/ File$[6]
240   !============================================================================
250   DIM Msus$[7],Text1$[80],Text2$[80],Wait$[1],Header$(99)[80]
260   !
270   GOSUB Keys_off
280   OUTPUT KBD;"K{";
290   !
300 Set_variables:                                       !
310   Line=0
320   Max_channels=32
330   Msus$=":,700,0"
340   !
350 Start:                                               !Display screen
360   Text1$=" TEST PURGE PROGRAM "
370   Text2$=" GEOTECHnical resources ltd. "
380   PRINT TABXY(27,2);CHR$(129)
390   PRINT TABXY((80-LEN(Text1$)) DIV 2,3);Text1$
400   PRINT TABXY((80-LEN(Text2$)) DIV 2,4);Text2$
410   !
420   GOSUB Keys
430   !
440 Spin:                                                !
450   GOSUB Keys_on
460   LOOP
470   END LOOP
480   !
490   !Subroutines++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
500   !
510 Keys:                                                !
520   SELECT Msus$
530   CASE ":,700,0"
540     ON KEY 1 LABEL "  HARD    DISK  ",3 GOSUB Chg_disk
550   CASE ":,700,1"
560     ON KEY 1 LABEL " FLOPPY   DISK  ",3 GOSUB Chg_disk
570   END SELECT
580   ON KEY 2 LABEL "                ",3 GOSUB Nothing
590   ON KEY 3 LABEL " SELECT  INDEX  ",3 GOSUB Select_index
600   ON KEY 4 LABEL "                ",3 GOSUB Nothing
```

```
610   ON KEY 5 LABEL "                ",3 GOSUB Nothing
620   ON KEY 6 LABEL "                ",3 GOSUB Nothing
630   ON KEY 6 LABEL "                ",3 GOSUB Nothing
640   ON KEY 7 LABEL "                ",3 GOSUB Nothing
650   ON KEY 8 LABEL "  EXIT   PURGE  ",3 GOTO Exit_program
660   RETURN
670   !
680 Chg_disk:                                             !
690   GOSUB Keys_off
700   OFF KEY
710   SELECT Msus$
720   CASE ":,700,0"
730     Msus$=":,700,1"
740     GOSUB Keys
750     ON KEY 1 LABEL " FLOPPY   DISK  ",3 GOSUB Chg_disk
760   CASE ":,700,1"
770     Msus$=":,700,0"
780     GOSUB Keys
790     ON KEY 1 LABEL "  HARD    DISK  ",3 GOSUB Chg_disk
800   END SELECT
810   GOSUB Keys_on
820   RETURN
830   !
840 Nothing:                                              !Unused key
850   BEEP
860   RETURN
870   !
880 Select_index:                                         !
890   GOSUB Keys_off
900   OUTPUT KBD;"K";
910   PRINT CHR$(128)
920   ON KEY 5 LABEL "                ",3 GOSUB Nothing
930   ON KEY 6 LABEL "                ",3 GOSUB Nothing
940   Index$=" "
950   DISP CHR$(129)
960   INPUT " Enter test series name. (1 to 3 alpha-numeric characters) ",Index$
970   DISP CHR$(128)
980   Index$=UPC$(Index$)
990   SELECT LEN(Index$)
1000  CASE >3
1010    PRINT TABXY(1,19);"Enter 3 characters only -- e.g. PRP "
1020    GOTO Select_index
1030  CASE <3
1040    Index$=Index$&RPT$("_",3-LEN(Index$))&"_INDEX"
1050  CASE =3
1060    Index$=Index$&"_INDEX"
1070  END SELECT
1080  !
1090 Read_index:                                          !
1100  ON ERROR GOTO Check_error
1110  ASSIGN @Index TO Index$&Msus$
1120  OFF ERROR
1130  ON END @Index RECOVER Exhausted
1140  ENTER @Index;Index_desc$
1150  FOR Test=1 TO SIZE(Header$,1)
1160    ENTER @Index;Test_hdr$(Test),Test_time(Test),Test_status(Test)
1170  NEXT Test
1180 Exhausted:                                           !
1190  OFF END @Index
1200  ASSIGN @Index TO *
```

```
1210 Build_header:                                         !
1220  REDIM Header$(MAX(Test-1,1))
1230  FOR Count=1 TO Test-1
1240    Time$=TIME$(Test_time(Count))
1250    Date$=DATE$(Test_time(Count))
1260    SELECT Test_status(Count)
1270    CASE 0
1280      Status$="OK"
1290    CASE 1
1300      Status$="NG"
1310    END SELECT
1320    Header$(Count)=Test_hdr$(Count)&" -- "&Time$&" -- "&Date$&" -- "&Status$
1330  NEXT Count
1340  MAT SORT Header$(*)[1,6]
1350  PRINT TABXY(1,1);"Test series: ";Index$[1,10]
1360  PRINT "Description: ";Index_desc$
1370  PRINT
1380  FOR Count=1 TO Test-1
1390    PRINT TAB((80-LEN(Header$(Count))) DIV 2);Header$(Count)
1400  NEXT Count
1410  PRINT
1420  STATUS 1,1;Line
1430  GOSUB Keys
1440  ON KEY 4 LABEL " SELECT   TEST  ",3 GOSUB Select_test
1450  GOSUB Keys_on
1460  RETURN
1470  !
1480 Select_test:                                          !
1490  GOSUB Keys_off
1500  Test_no=0
1510  DISP CHR$(129)
1520  INPUT " Enter file number to purge. (1 =< NUMBER =< 99) ",Test_no
1530  DISP CHR$(128)
1540  IF Test_no<1 OR Test_no>99 THEN GOTO Select_test
1550  IF Test_no<10 THEN
1560    File$=Index$[1,3]&"0"&VAL$(Test_no)
1570  ELSE
1580    File$=Index$[1,3]&VAL$(Test_no)
1590  END IF
1600  No_test=0
1610  ALLOCATE Files$(Max_channels+1)[80]
1620  CAT Msus$ TO Files$(*);SELECT File$,COUNT No_test,NO HEADER
1630  SELECT No_test
1640  CASE 0
1650    PRINT TABXY(1,19);"File ";File$;" not found."
1660  CASE 1 TO 99
1670    CONTROL 1,1;Line
1680    PRINT CHR$(129);" WARNING!!!  These files will be purged!!! ";CHR$(128)
1690    ON ERROR GOTO Done
1700    FOR Count=1 TO No_test+1 STEP 4
1710      PRINT Files$(Count)[1,10];TAB(15);Files$(Count+1)[1,10];TAB(30);Files$
1720    NEXT Count
1730 Done:   !
1740    PRINT
1750  END SELECT
1760  GOSUB Keys
1770  ON KEY 4 LABEL " SELECT   TEST  ",3 GOSUB Select_test
1780  ON KEY 5 LABEL " DELETE  INDEX  ",3 GOSUB Purge_index
1790  IF Test_no>0 THEN
1800    ON KEY 6 LABEL " DELETE   TEST  ",3 GOSUB Purge_files
```

```
1810  END IF
1820  GOSUB Keys_on
1830  RETURN
1840  !
1850 Purge_index:                                          !
1860  GOSUB Keys_off
1870  Ans$="n"
1880  DISP CHR$(129)
1890  INPUT " Are you sure? (Y/N) ",Ans$
1900  DISP CHR$(128)
1910  Flag=0
1920  IF UPC$(Ans$[1])="Y" THEN
1930    CAT Msus$ TO Files$(*);SELECT Index$[1,4],COUNT Flag,NO HEADER
1940    IF Flag>1 THEN
1950      PRINT TABXY(1,19);"CANNOT CONTINUE...OTHER TEST SERIES FILES EXIST!!!"
1960      DISP CHR$(129)
1970      INPUT " Press ENTER or RETURN for list of remaining files. ",Wait$
1980      DISP CHR$(128)
1990      CONTROL 1,1;Line
2000      PRINT "List of remaining files.                                  "
2010      FOR Count=1 TO Flag STEP 4
2020        PRINT Files$(Count)[1,10];TAB(15);Files$(Count+2)[1,10];TAB(30);File
2030      NEXT Count
2040      DISP CHR$(129)
2050      INPUT " Press ENTER or RETURN to continue. ",Wait$
2060      DISP CHR$(128)
2070    ELSE
2080      ON ERROR GOTO Check_error
2090      PURGE Index$&Msus$
2100      OFF ERROR
2110    END IF
2120  END IF
2130  GOSUB Keys
2140  IF Flag=1 THEN
2150    ON KEY 4 LABEL " SELECT   TEST  ",3 GOSUB Select_test
2160  END IF
2170  IF Flag=0 THEN
2180    ON KEY 6 LABEL " DELETE   TEST  ",3 GOSUB Purge_files
2190  END IF
2200  GOSUB Keys_on
2210  RETURN
2220  !
2230 Purge_header:                                         !
2240  GOSUB Keys_off
2250  File$=File$&"_HDR"
2260  DISP CHR$(129)
2270  Ans$="n"
2280  DISP " Are you sure? (Y/N) ",Ans$
2290  DISP CHR$(128)
2300  IF UPC$(Ans$[1])="Y" THEN
2310    ON ERROR GOTO Check_error
2320    PURGE File$&Msus$
2330    OFF ERROR
2340    !
2350 Purge_files:                                          !
2360    GOSUB Keys_off
2370    ON ERROR GOTO Check_error
2380    FOR Count=1 TO No_test
2390      IF Files$(Count)[1,10]<>File$ THEN
2400        PURGE Files$(Count)[1,10]&Msus$
```

```
2410      END IF
2420 Next_file:                                       !
2430    NEXT Count
2440  END IF
2450  OFF ERROR
2460  DEALLOCATE Files$(*)
2470  GOSUB Keys
2480  ON KEY 4 LABEL " SELECT   TEST  ",3 GOSUB Select_test
2490  GOSUB Keys_on
2500  RETURN
2510  !
2520 Keys_off:                                        !
2530  CONTROL 1,12;1
2540  OFF KEY
2550  RETURN
2560  !
2570 Keys_on:                                         !
2580  CONTROL 1,12;2
2590  RETURN
2600  !
2610 Check_error:                                     !
2620  SELECT ERRN
2630  CASE 56
2640    PRINT TABXY(1,19);"INDEX file ";Index$;" does not exist!!"
2650    BEEP
2660    DISP CHR$(129)
2670    INPUT " Press ENTER or RETURN to continue. ",Wait$
2680    DISP CHR$(128)
2690  CASE 80
2700    PRINT TABXY(1,19);"Disk not found -- insert a disk to continue."
2710    DISP CHR$(129)
2720    BEEP
2730    INPUT " Press ENTER or RETURN to continue. ",Wait$
2740    DISP CHR$(128)
2750    PRINT TABXY(1,19);RPT$(" ",80)
2760  CASE ELSE
2770    PRINT TABXY(1,19);"Unexpected error.....cannot continue!!"
2780    PRINT ERRM$
2790    GOSUB Keys_on
2800    PAUSE
2810  END SELECT
2820  IF ERRN=56 THEN GOTO Select_index
2830  RETURN
2840  !
2850 Exit_program:                                    !
2860  OUTPUT KBD;"K";
2870  END
2880  !
2890  !************************************************************************
```

```
10!RE-STORE "DISK_COPY"
20  !  *********************************************************************
30  !  ¦Name       : DISK_COPY                      Revision: 1.0             ¦
40  !  ¦Programmer: N Chalk                         Date:     13 Jun 88       ¦
50  !  ¦----------------------------------------------------------------------¦
60  !  ¦Description: This program copies all the files on a target diskette to ¦
70  !  ¦             a source diskette. If the target disk is not formatted, it ¦
80  !  ¦             traps the error and format it.                            ¦
90  !  *********************************************************************
100   OPTION BASE 1
110   !
120 Next_disk:  !
130   PRINT TABXY(1,19);"Copying Disk 0 (source) to Disk 1 (target)."
140   ON ERROR GOSUB File_error
150   COPY ":,702,0" TO ":,702,1"
160   OFF ERROR
170   PRINT TABXY(1,19);RPT$(" ",80)
180   BEEP
190   BEEP
200   INPUT "Done! Insert next set and press enter.",Ans$
210   GOTO Next_disk
220   !
230 File_error:  !
240   SELECT ERRN
250   CASE 80
260     INPUT "Place source(target) disk in drive 0(1) and press enter.",Ans$
270   CASE 83
280     INPUT "Target disk write protected! Correct and press enter.",Ans
290   CASE 85
300     PRINT TABXY(1,19);"Initializing target disk...                            "
310     INITIALIZE ":,702,1"
320     PRINT TABXY(1,19);"Copying Disk 0 (source) to Disk 1 (target)...          "
330   CASE ELSE
340     PRINT TABXY(1,19);ERRM$
350     PAUSE
360   END SELECT
370   RETURN
380   END
```

```
10!RE-STORE "Test_copy:,700,0"
20  !  ***********************************************************************
30  ! |                           "TESTCOPY"                                 |
40  ! |                                                                       |
50  ! |Calling name: Test_copy                        Version: 2.0            |
60  ! |Programmer  : N Chalk                          Date   : 22 Apr 1988
70  ! |-----------------------------------------------------------------------|
80  ! |Description:
90  ! | - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - |
100 ! |_______________________________________________________________________|
110 ! |Modification history                              |Date      |By
120 ! |---------------------------------------------------|----------|--------|
130 ! | 1.                                                |          |        |
140 ! | 2.                                                |          |        |
150 ! | 3.                                                |          |        |
160 !  **********************************************************************
170   OPTION BASE 1
180   COM /Index/ Index$[25],Index_desc$[80]
190   COM /Header/ Test_hdr$(99)[10],Test_time(99),INTEGER Test_status(99)
200   COM /String/ Time$[8],Date$[11],Status$[2]
210   COM /Files/ File$[6]
220   !==========================================================================
230   DIM Msus1$[7],Msus2$[7],Text1$[80],Text2$[80],Wait$[1],Header$(99)[80]
240   !
250   GOSUB Keys_off
260   OUTPUT KBD;"K{";
270   !
280 Set_variables:                                    !
290   Line=0
300   Max_channels=32
310   Msus1$=":,700,0"
320   Msus2$=":,700,1"
330   !
340 Start:                                            !Display screen
350   Text1$=" TEST COPY PROGRAM "
360   Text2$=" GEOTECHnical resources ltd. "
370   PRINT TABXY(27,2);CHR$(129)
380   PRINT TABXY((80-LEN(Text1$)) DIV 2,3);Text1$
390   PRINT TABXY((80-LEN(Text2$)) DIV 2,4);Text2$
400   !
410   GOSUB Keys
420   !
430 Spin:                                             !
440   GOSUB Keys_on
450   LOOP
460   END LOOP
470   !
480   !Subroutines+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
490   !
500 Keys:                                             !
510   SELECT Msus1$
520   CASE ":,700,0"
530     ON KEY 1 LABEL " HARD >  FLOPPY ",3 GOSUB Chg_disk
540   CASE ":,700,1"
550     ON KEY 1 LABEL " FLOPPY  > HARD ",3 GOSUB Chg_disk
560   END SELECT
570   ON KEY 2 LABEL "                ",3 GOSUB Nothing
580   ON KEY 3 LABEL " SELECT  INDEX  ",3 GOSUB Select_index
590   ON KEY 4 LABEL "                ",3 GOSUB Nothing
600   ON KEY 5 LABEL "                ",3 GOSUB Nothing
```

```
610   ON KEY 6 LABEL "                    ",3 GOSUB Nothing
620   ON KEY 6 LABEL "                    ",3 GOSUB Nothing
630   ON KEY 7 LABEL "                    ",3 GOSUB Nothing
640   ON KEY 8 LABEL "  EXIT  TESTCOPY",3 GOTO Exit_program
650   RETURN
660   !
670 Chg_disk:                                         !
680   GOSUB Keys_off
690   OFF KEY
700   SELECT Msus1$
710   CASE ":,700,0"
720     Msus1$=":,700,1"
730     Msus2$=":,700,0"
740     GOSUB Keys
750     ON KEY 1 LABEL " FLOPPY  > HARD ",3 GOSUB Chg_disk
760   CASE ":,700,1"
770     Msus1$=":,700,0"
780     Msus2$=":,700,1"
790     GOSUB Keys
800     ON KEY 1 LABEL " HARD >  FLOPPY ",3 GOSUB Chg_disk
810   END SELECT
820   GOSUB Keys_on
830   RETURN
840   !
850 Nothing:                                          !Unused key
860   BEEP
870   RETURN
880   !
890 Select_index:                                     !
900   GOSUB Keys_off
910   OUTPUT KBD;"K";
920   PRINT CHR$(128)
930   ON KEY 5 LABEL "                    ",3 GOSUB Nothing
940   ON KEY 6 LABEL "                    ",3 GOSUB Nothing
950   Index$=" "
960   DISP CHR$(129)
970   INPUT " Enter test series name. (1 to 3 alpha-numeric characters) ",Index$
980   DISP CHR$(128)
990   Index$=UPC$(Index$)
1000  SELECT LEN(Index$)
1010  CASE >3
1020    BEEP
1030    PRINT TABXY(1,19);"Enter 3 characters only -- e.g. PRP "
1040    WAIT 1
1050    GOTO Select_index
1060  CASE <3
1070    Index$=Index$&RPT$("_",3-LEN(Index$))&"_INDEX"
1080  CASE =3
1090    Index$=Index$&"_INDEX"
1100  END SELECT
1110  !
1120 Read_index:                                      !
1130  ON ERROR GOTO Check_error
1140  ASSIGN @Index TO Index$&Msus1$
1150  OFF ERROR
1160  ON END @Index RECOVER Exhausted
1170  ENTER @Index;Index_desc$
1180  FOR Test=1 TO SIZE(Header$,1)
1190    ENTER @Index;Test_hdr$(Test),Test_time(Test),Test_status(Test)
1200  NEXT Test
```

```
1210 Exhausted:                                          !
1220  OFF END @Index
1230  ASSIGN @Index TO *
1240 Build_header:                                       !
1250  REDIM Header$(Test-1)
1260  FOR Count=1 TO Test-1
1270    Time$=TIME$(Test_time(Count))
1280    Date$=DATE$(Test_time(Count))
1290    SELECT Test_status(Count)
1300    CASE 0
1310      Status$="OK"
1320    CASE 1
1330      Status$="NG"
1340    END SELECT
1350    Header$(Count)=Test_hdr$(Count)&" -- "&Time$&" -- "&Date$&" -- "&Status$
1360  NEXT Count
1370  MAT SORT Header$(*)[1,6]
1380  PRINT TABXY(1,1);"Test series: ";Index$[1,10]
1390  PRINT "Description: ";Index_desc$
1400  PRINT
1410  FOR Count=1 TO Test-1
1420    PRINT TAB((80-LEN(Header$(Count))) DIV 2);Header$(Count)
1430  NEXT Count
1440  PRINT
1450  STATUS 1,1;Line
1460  GOSUB Keys
1470  ON KEY 4 LABEL " SELECT   TEST  ",3 GOSUB Select_test
1480  GOSUB Keys_on
1490  RETURN
1500  !
1510 Select_test:                                        !
1520  GOSUB Keys_off
1530  Test_no=0
1540  DISP CHR$(129)
1550  INPUT " Enter file number to copy. (1 =< NUMBER =< 99) ",Test_no
1560  DISP CHR$(128)
1570  IF Test_no<1 OR Test_no>99 THEN GOTO Select_test
1580  IF Test_no<10 THEN
1590    File$=Index$[1,3]&"0"&VAL$(Test_no)
1600  ELSE
1610    File$=Index$[1,3]&VAL$(Test_no)
1620  END IF
1630  No_test=0
1640  ALLOCATE Files$(Max_channels+1)[80]
1650  CAT Msus1$ TO Files$(*);SELECT File$,COUNT No_test,NO HEADER
1660  IF No_test=0 THEN
1670    PRINT TABXY(1,19);"File ";File$;" not found."
1680    GOTO Select_test
1690  END IF
1700  MAT SORT Files$(*)[1,10]
1710  CONTROL 1,1;Line
1720  PRINT "Files to be copied."
1730  ON ERROR GOTO Done
1740  FOR Count=1 TO No_test+1 STEP 4
1750    PRINT Files$(Count)[1,10];TAB(15);Files$(Count+1)[1,10];TAB(30);Files$(C
1760  NEXT Count
1770 Done:                                               !
1780  GOSUB Keys
1790  ON KEY 4 LABEL " SELECT   TEST  ",3 GOSUB Select_test
1800  ON KEY 5 LABEL "  COPY   INDEX  ",3 GOSUB Copy_index
```

```
1810  ON KEY 6 LABEL "  COPY    TEST  ",3 GOSUB Copy_files
1820  GOSUB Keys_on
1830  RETURN
1840  !
1850 Copy_index:                                    !
1860  GOSUB Keys_off
1870  ON ERROR GOTO Check_error
1880  SELECT Flag
1890  CASE 0
1900    COPY Index$&Msus1$ TO Index$&Msus2$
1910    Flag=1
1920  CASE 1
1930    DISP CHR$(129)
1940    INPUT " Index already copied. Copy again? (Y/N) ",Ans$
1950    DISP CHR$(128)
1960    IF UPC$(Ans$[1])="Y" THEN
1970      COPY Index$&Msus1$ TO Index$&Msus2$
1980    END IF
1990  END SELECT
2000  OFF ERROR
2010  GOSUB Keys
2020  ON KEY 4 LABEL " SELECT   TEST  ",3 GOSUB Select_test
2030  ON KEY 6 LABEL "  COPY    TEST  ",3 GOSUB Copy_files
2040  GOSUB Keys_on
2050  RETURN
2060  !
2070 Copy_files:                                    !Copy files
2080  GOSUB Keys_off
2090  !
2100  ALLOCATE Test_header$[10]                     !Copy test header file
2110  Test_header$=File$&"_HDR"
2120  ON ERROR GOSUB Check_error
2130  COPY Test_header$&Msus1$ TO Test_header$&Msus2$
2140  OFF ERROR
2150  DEALLOCATE Test_header$
2160  !
2170  GOSUB Keys_off                                !Copy test data files
2180  ON ERROR GOSUB Check_error
2190  FOR Count=1 TO No_test-1
2200    IF Files$(Count)[1,10]<>File$ THEN
2210      COPY Files$(Count)[1,10]&Msus1$ TO Files$(Count)[1,10]&Msus2$
2220    END IF
2230 Next_file:                                     !
2240  NEXT Count
2250  OFF ERROR
2260  DEALLOCATE Files$(*)
2270  GOSUB Keys
2280  ON KEY 4 LABEL " SELECT   TEST  ",3 GOSUB Select_test
2290  GOSUB Keys_on
2300  RETURN
2310  !
2320 Keys_off:                                      !
2330  CONTROL 1,12;1
2340  OFF KEY
2350  RETURN
2360  !
2370 Keys_on:                                       !
2380  CONTROL 1,12;2
2390  RETURN
2400  !
```

```
2410 Check_error:                                          !
2420  SELECT ERRN
2430  CASE 54
2440    IF ERRL(1900) OR ERRL(1970) THEN
2450      OFF ERROR
2460      OFF KEY
2470      PRINT TABXY(1,19);"Duplicate file -- ";Index$[1,10]
2480      GOSUB Keys
2490      ON KEY 4 LABEL " SELECT   TEST  ",3 GOSUB Select_test
2500      ON KEY 6 LABEL "  COPY    TEST  ",3 GOSUB Copy_files
2510      GOSUB Keys_on
2520    END IF
2530    IF ERRL(2130) THEN
2540      PRINT TABXY(1,19);"Duplicate file -- ";File$
2550      GOTO Copy_files
2560    END IF
2570    IF ERRL(2210) THEN
2580      PRINT "Duplicate file -- ";Files$(Count)[1,10]
2590      GOTO Next_file
2600    END IF
2610  CASE 56
2620    PRINT TABXY(1,19);"INDEX file ";Index$;" does not exist!!"
2630    BEEP
2640    DISP CHR$(129)
2650    INPUT " Press ENTER or RETURN to continue. ",Wait$
2660    DISP CHR$(128)
2670  CASE 64
2680    SELECT Msus2$
2690    CASE ":,700,0"
2700      BEEP
2710      PRINT TABXY(1,19);"Hard disk full.....cannot continue!!"
2720      PAUSE
2730    CASE ":,700,1"
2740      PRINT TABXY(1,19);"Disk full.....insert next disk."
2750      BEEP
2760      DISP CHR$(129)
2770      INPUT " Press ENTER or RETURN to continue. ",Wait$
2780      DISP CHR$(128)
2790      PRINT TABXY(1,19);RPT$(" ",80)
2800    END SELECT
2810  CASE 80
2820    PRINT TABXY(1,19);"Disk not found -- insert a disk to continue."
2830    DISP CHR$(129)
2840    BEEP
2850    INPUT " Press ENTER or RETURN to continue. ",Wait$
2860    DISP CHR$(128)
2870    PRINT TABXY(1,19);RPT$(" ",80)
2880  CASE ELSE
2890    PRINT TABXY(1,19);"Unexpected error.....cannot continue!!"
2900    PRINT ERRM$
2910    PAUSE
2920  END SELECT
2930  IF ERRN=56 THEN GOTO Select_index
2940  RETURN
2950  !
2960 Exit_program:                                         !
2970  OUTPUT KBD;"K";
2980  GOSUB Keys_on
2990  END
3000  !****************************************************************
```

```
3010  |*************************************************************************
```

```
10 !RE-STORE "PROP DAS:.700.0"
20  !  ******************************************************************
30  ! |                 PROP BUSTERS DATA ACQUISITION PROGRAM             |
40  ! |                                                                    |
50  ! |Calling name: PROP_DAS                       Revision: 1.0         |
60  ! |Programmers : N Chalk                        Date     : 20 Apr 1988|
70  ! |--------------------------------------------------------------------|
80  ! |Description:                                                        |
90  ! |                                                                    |
100 ! |                                                                    |
110 ! |                                                                    |
120 ! |                                                                    |
130 ! | - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -|
140 ! |Root programmes: PERDFRAC /  5 Mar 1987                             |
150 ! |                 KIGDAS   / 16 May 1986                             |
160 ! |____________________________________________________________________|
170 ! |Modification History                          |Date       |By       |
180 ! |----------------------------------------------|-----------|---------|
190 ! | 1.                                           |           |         |
200 ! | 2.                                           |           |         |
210 ! | 3.                                           |           |         |
220 !  ******************************************************************
230   OPTION BASE 1
240   COM /Ad_setup1/ INTEGER Card_no,Dvm_flag,No_cards,No_channels,Max_cards
250   COM /Ad_setup2/ INTEGER Max_channels,No_windows,Trigger(2)
260   COM /Ad_setup3/ Duration(2),No_samples(2),Period(2),Sample_rate(2)
270   COM /Ad_setup4/ Ad_gain(2,16,3),Mode$(2,16)[1],Preset$(2,2)[128]
280   COM /Arb_gen/ Arb_addr
290   COM /Files_1/ Index_file$[10],Test_hdr$[10],File_id$(2,16,2)[10]
300   COM /Files_2/ Msus$[10],Temp_files$(2)[10],Hdr_size
310   COM /Infotek/ INTEGER Ad_addr(2),Code(0:200),Entry(3),Offset
320   COM /Test_data/ Labels$(2,16,3)[8],Gains(2,16,3),Test_time
330   !=====================================================================
340 Test_header:                                    !Test description header
350   DIM Text$(3)[80]
360   Text$(1)="GEOTECHnical resources ltd"
370   Text$(2)="PROP BUSTERS"
380   Text$(3)="PROJECT NUMBER: 9448"
390   !
400 Restart:                                        !Initialize computer
410   PRINTER IS CRT
420   OUTPUT KBD;"K";
430   PRINT CHR$(128)
440   DISP CHR$(128)
450   CONTROL 2,2;1
460   !
470 Save:                                           !Save last changes!!!
480   DISP CHR$(129)
490   INPUT " Save last changes? (Y/N) ",Ans$
500   DISP CHR$(128)
510   IF UPC$(Ans$[1,1])="Y" THEN
520     RE-STORE "PROP_DAS:,700,0"
530   ELSE
540     IF UPC$(Ans$[1,1])<>"N" THEN
550       BEEP
560       GOTO Save
570     END IF
580   END IF
590   !
```

```
600 Set_variables:                                    !Define DAS variables here
610   Arb_addr=703                                    !ARB GEN HPIB addr
620   Arb_rst=0                                       !Auto-reset ARB = 0
630   Card_no=1                                       !DAS single card default
640   Dvm_flag=0                                      !Automates DAS if DVM on
650   Prt_flag=1                                      !Dump SETUP to PRT: set=1
660   Group=1                                         !Inc. data array by 32kwds
670   Hdr_size=20                                     !Test header size (blocks)
680   MAT Ad_addr= (0)                                !Physical addresses
690   MAT Ad_gain= (0)                                !
700   MAT Code= (0)                                   !INFOTEK ass'y code
710   MAT Duration= (0)                               !Data collection run-time
720   MAT Entry= (0)                                  !INFOTEK code entries
730   MAT File_id$= ("*")                             !
740   MAT Gains= (0)                                  !
750   MAT Labels$= ("*")                              !
760   MAT Mode$= ("*")                                !AD200 channel mode (S,D)
770   MAT No_samples= (0)                             !Total COUNT per card
780   MAT Period= (0)                                 !TIME in nanoseconds
790   MAT Preset$= ("*")                              !Partial AD200 cmd string
800   MAT Sample_rate= (0)                            !Hz per card
810   MAT Trigger= (0)                                !Internal=0, External=1
820   Max_cards=SIZE(Mode$,1)                         !1 to 4 AD200 cards
830   Max_channels=SIZE(Mode$,1)*SIZE(Mode$,2)        !Set via COM BLOCKS
840   Msus$=":,700,0"                                 !Data storage media
850   No_cards=2                                      !Set to max cards
860   No_channels=32                                  !Set to max channels
870   No_windows=1                                    !Iterations per test
880   Offset=0                                        !INFOTEK code data offset
890   Test_time=0                                     !Time test starts
900   !
910   FOR Window=1 TO No_windows                      !Setup temp data arrays
920     Temp_files$(Window)="TEMPDATA_"&VAL$(Window)
930   NEXT Window
940   !
950   REDIM Ad_addr(No_cards)                         !Set AD200 I/O address(es)
960   RESTORE
970   DATA 10,11
980   READ Ad_addr(*)
990   !
1000 Init_arb:                                        !Disable ARB GEN
1010   IF Arb_rst<>1 THEN
1020     Ans$="n"
1030     PRINT TABXY(1,19);CHR$(129);" WARNING!!! ";
1040     PRINT CHR$(128);" Check for nil ram pressure, personnel clear, etc."
1050     DISP CHR$(129)
1060     INPUT " Safe to reset ARB GEN? (Y/N) ",Ans$
1070     PRINT TABXY(1,19);RPT$(" ",80)
1080     DISP CHR$(128)
1090     IF UPC$(Ans$[1])<>"Y" THEN GOTO Init_arb
1100     PRINT TABXY(1,19);"Initializing Arb Gen..."
1110     ASSIGN @Arb TO Arb_addr
1120     ON TIMEOUT 7,20 GOTO No_arb
1150     OUTPUT @Arb;"Z"                              !(Reset)
1160     LOCAL @Arb                                   !(Return to local mode)
1170     OFF TIMEOUT
1180     ASSIGN @Arb TO *
1190     PRINT TABXY(1,19);RPT$(" ",80)
1200     Arb_rst=1
1210   END IF
```

```
1220  !
1230 Setup:!--------------------------------------------------------------------
1240  ! Setup operations:                                                       !
1250  !       -- sets up test index file                                        !
1260  !       -- sets up test parameters                                        !
1270  !       -- checks for sufficient memory and disk space                    !
1280  !       -- creates test record                                            !
1290  !       -- builds / modifies test information files                       !
1300  !-------------------------------------------------------------------------!
1310  PRINT TABXY(1,1)                                    !Print header
1320  FOR I=1 TO SIZE(Text$,1)
1330    PRINT TAB((80-LEN(Text$(I))) DIV 2);Text$(I)
1340  NEXT I
1350  PRINT
1360  !
1370  Setup_index
1380  Purge_files(0)
1390  Setup_table
1400  Setup_test
1410  !
1420  Data_words=FNMem_needed                             !Check memory required
1430  Mem_words=FNMem_space
1440  PRINT "Require...:";Data_words;" words in memory for logging."
1450  PRINT "Have......:";Mem_words;" words in memory available."
1460  IF Mem_words<Data_words THEN
1470    DISP CHR$(129);" Insufficient memory.  Cannot continue. "
1480    BEEP
1490    STOP
1500  END IF
1510  !
1520  Dataspace=FNDisk_needed                             !Check disk space req'd
1530  Diskspace=FNDisk_space(Msus$)
1540  PRINT "Require...:";Dataspace;" words on disk for logging."
1550  PRINT "Have......:";Diskspace;" words on disk available."
1560  PRINT
1570  IF Diskspace<Dataspace THEN
1580    DISP CHR$(129);" Insufficient disk space.  Cannot continue. "
1590    BEEP
1600    STOP
1610  END IF
1620  !
1630  GOSUB Print_setup                                   !Dump setup to CRT
1640  !
1650  Ans$="y"                                            !Check setup table
1660  DISP CHR$(129)                                      !okay, send it to the PRT
1670  INPUT " Test data okay? (default is yes) ",Ans$
1680  DISP CHR$(128)
1690  IF UPC$(Ans$[1,1])<>"Y" THEN
1700    GOTO Restart
1710  ELSE
1720    IF Prt_flag=1 THEN
1730 Cycle:Ans$="y"
1740      BEEP
1750      DISP CHR$(129)
1760      INPUT " Is printer at top-of-form? (default is yes) ",Ans$
1770      DISP CHR$(128)
1780      IF UPC$(Ans$[1,1])<>"Y" THEN Cycle
1790      ON TIMEOUT 7,.5 GOSUB Find_printer
1800      PRINTER IS PRT
1810      OUTPUT PRT;"";
```

```
1820        GOSUB Print_setup
1830        PRINT "
```

```
                    Transducer table for test #";Test_hdr$
1840      PRINT
1850      LIST Card1,End_transducers
1860      PRINT "
```

```
1870      OFF TIMEOUT
1880      PRINTER IS CRT
1890    END IF
1900  END IF
1910  !
1920  Write_header                                    !Create test header file
1930 !Read_header                                     ! <Debugging aid>
1940 Logging:!-----------------------------------------------------------------!
1950  !Logging operations -- initializes AD-200 card(s)                        !
1960  !                   -- displays transducer voltages before test (DVM)    !
1970  !                   -- acquires data                                     !
1980  !------------------------------------------------------------------------!
1990  Init_das_cmd                                    !Build command array
2000  Voltmeter(1)                                    ! (Window = 1)
2010  !
2020  SELECT No_cards                                 !Log data
2030 Das1:                                            ! (From One Ad-200 card)
2040  CASE 1
2050    FOR Window=1 TO No_windows
2060      Buff_size=No_samples(Window)
2070      SELECT Window
2080      CASE 1
2090        ASSIGN @Ad_buff1 TO BUFFER [Buff_size*2];FORMAT OFF,WORD
2100      CASE 2
2110        ASSIGN @Ad_buff2 TO BUFFER [Buff_size*2];FORMAT OFF,WORD
2120      END SELECT
2130    NEXT Window
2140    !
2150    FOR Window=1 TO No_windows
2160      SELECT Window
2170      CASE 1
2180        Das_1_ad200(@Ad_buff1,Window)
2190      CASE 2
2200        Das_1_ad200(@Ad_buff2,Window)
2210      END SELECT
2220    NEXT Window
2230    !
2240    FOR Window=1 TO No_windows
2250      SELECT Window
2260      CASE 1
2270        Download_buffer(@Ad_buff1,Temp_files$(Window),Msus$)
2280      CASE 2
2290        Download_buffer(@Ad_buff2,Temp_files$(Window),Msus$)
2300      END SELECT
2310    NEXT Window
2320    !
2330    ASSIGN @Ad_buff1 TO *
2340    ASSIGN @Ad_buff2 TO *
2350 Das4:                                            ! (From 2/4 Ad-200 cards)
2360  CASE 2 TO 4
2370    !
2380    Channels=No_channels/No_cards                 !Calc data array dim.
2390    ALLOCATE Samples(No_windows),Groups(No_windows)
2400    FOR Window=1 TO No_windows
2410      Groups(Window)=1+(No_samples(Window) DIV 32768)
2420      IF (No_samples(Window)/Channels) MOD Groups(Window)=0 THEN
2430        Samples(Window)=(No_samples(Window)/Channels) DIV Groups(Window)
2440      ELSE
2450        Samples(Window)=1+((No_samples(Window)/Channels) DIV Groups(Window))
```

```
2460        END IF
2470      NEXT Window
2480      !
2490      FOR Window=1 TO No_windows                          !Setup data array(s)
2500        SELECT Window
2510        CASE 1
2520          ALLOCATE INTEGER Ad_array1(Groups(Window),Samples(Window),Channels,N
2530        CASE 2
2540          ALLOCATE INTEGER Ad_array2(Groups(Window),Samples(Window),Channels,N
2550        END SELECT
2560      NEXT Window
2570      DEALLOCATE Samples(*),Groups(*)
2580      !
2590      FOR Window=1 TO No_windows
2600        SELECT Window
2610        CASE 1
2620          Das_4_ad200(Window,Ad_array1(*))
2630        CASE 2
2640          Das_4_ad200(Window,Ad_array2(*))
2650        END SELECT
2660      NEXT Window
2670        !
2680      FOR Window=1 TO No_windows
2690        SELECT Window
2700        CASE 1
2710          Download_array(Ad_array1(*),Temp_files$(Window),Msus$)
2720        CASE 2
2730          Download_array(Ad_array2(*),Temp_files$(Window),Msus$)
2740        END SELECT
2750      NEXT Window
2760      !
2770      FOR Window=1 TO No_windows
2780        SELECT Window
2790        CASE 1
2800          DEALLOCATE Ad_array1(*)
2810        CASE 2
2820          DEALLOCATE Ad_array2(*)
2830        END SELECT
2840      NEXT Window
2850    END SELECT
2860 Demux:!!-----------------------------------------------------------!
2870    ! Demultiplexing operations                                      !
2880    !     -- demultiplexes and stores data                           !
2890    !     -- updates site file                                       !
2900    !----------------------------------------------------------------!
2910    Demux_data
2920    Update_index                                    !Update index file
2930 !Read_index                                       ! <Debugging aid>
2940    !
2950    BEEP 400,.25                                    !Sign off
2960    BEEP 300,.25
2970    BEEP 200,.25
2980    BEEP 100,.25
2990    DISP "Ende!!"
3000    STOP
3010    !+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++!
3020    !Subroutines                                                      !
3030    !+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++!
3040 No_arb:                                          !Device not presnt routine
3050    BEEP
```

```
3060  PRINT TABXY(1,19);"ARB GEN not present. Check power, etc."
3070  DISP CHR$(129)
3080  INPUT " Try to reset ARB GEN again? ",Ans$
3090  DISP CHR$(128)
3100  IF UPC$(Ans$[1])="Y" THEN
3110    GOTO Init_arb
3120  ELSE
3130    GOTO No_arb
3140  END IF
3150  !
3160 Print_setup:                                        !Dump test setup routine
3170  ON TIMEOUT 7,.5 GOSUB Find_printer
3180  IF SYSTEM$("PRINTER IS")="701" THEN
3190    OUTPUT PRT;""                                   !BOLD print on
3200    FOR I=1 TO SIZE(Text$,1)                         ! (From 'Test_header')
3210      PRINT TAB((80-LEN(Text$(I))) DIV 2);Text$(I)
3220    NEXT I
3230    OUTPUT PRT;""                                   !BOLD print off
3240    PRINT
3250    PRINT
3260    PRINT "Date: ";DATE$(TIMEDATE)
3270    PRINT "Time: ";TIME$(TIMEDATE)
3280    PRINT
3290  END IF
3300  PRINT "Test series......";" "&Test_hdr$[1,3]
3310  PRINT "Test number......";VAL(Test_hdr$[4,5])
3320  PRINT
3330  FOR Window=1 TO No_windows
3340    PRINT "*** Window";Window;"***"
3350    PRINT "Test duration .................";Duration(Window);"Second(s)"
3360    SELECT Period(Window)
3370    CASE <10^3
3380      PRINT "AD-200 sample period...........";Period(Window);"Nanoseconds"
3390    CASE >=10^6
3400      PRINT "AD-200 sample period...........";Period(Window)/10^6;"Milli-se
3410    CASE ELSE
3420      PRINT "AD-200 sample period...........";Period(Window)/10^3;"Micro-se
3430    END SELECT
3440    PRINT "Sample rate, aggregate .........";Sample_rate(Window);"Hz."
3450    PRINT "Sample rate per channel ........";Sample_rate(Window) DIV (No_cha
3460    PRINT "Number of samples per channel ..";(No_samples(Window)*No_cards) D
3470    PRINT "Total number of samples ........";No_samples(Window)*No_cards;"wo
3480    SELECT Trigger(Window)
3490    CASE 0
3500      PRINT "Trigger source .................";" INTERNAL"
3510    CASE 1
3520      PRINT "Trigger source .................";" EXTERNAL"
3530    END SELECT
3540  NEXT Window
3550  PRINT "Number of cards ................";No_cards
3560  PRINT "Number of channels per card ....";No_channels/No_cards
3570  PRINT "Total number of channels .......";No_channels
3580  OFF TIMEOUT
3590  RETURN
3600  !
3610 Find_printer:                                        !
3620  Ans$="y"
3630  PRINTER IS CRT
3640  PRINT TABXY(1,19);"
```

```
                         I can't seem to find the printer anywhere."
3650  BEEP
3660  DISP CHR$(129)
3670  INPUT " Have you found it yet? (default is yes) ",Ans$
3680  DISP CHR$(128)
3690  IF UPC$(Ans$[1,1])<>"Y" THEN Find_printer
3700  PRINT TABXY(1,19);RPT$(" ",80)
3710  PRINTER IS PRT
3720  RETURN
3730  END
3740  !*************************************************************************
3750  !*************************************************************************
3760 Build_files:SUB Build_files(File_records,Ch_id$(*))
3770  !
3780  !This module creates the channel files on a mass storage media specified
3790  !by MSUS$.
3800  !
3810  !Inputs:
3820  !    File_records = number of records in each channel file
3830  !=========================================================================
3840    OPTION BASE 1
3850    COM /Ad_setup1/ INTEGER Card_no,Dvm_flag,No_cards,No_channels,Max_cards
3860    COM /Ad_setup2/ INTEGER Max_channels,No_windows,Trigger(*)
3870    COM /Files_1/ Index_file$,Test_hdr$,File_id$(*)
3880    COM /Files_2/ Msus$,Temp_files$(*),Hdr_size
3890    !-----------------------------------------------------------------------
3900    INTEGER Cd,Ch,Chan,Window
3910    !
3920    DISP "Building new channel files."
3930    !
3940    Chan=0                                        !Build demuxing file array
3950    FOR Wdw=1 TO No_windows
3960      FOR Ch=1 TO No_channels/No_cards
3970        FOR Cd=1 TO No_cards
3980          Chan=Chan+1
3990          Ch_id$(Chan,Wdw)=File_id$(Cd,Ch,Wdw)
4000        NEXT Cd
4010      NEXT Ch
4020    NEXT Wdw
4030    !
4040    FOR Wdw=1 TO No_windows                       !Create files on MSU
4050      FOR Ch=1 TO No_channels
4060        CREATE BDAT Ch_id$(Ch,Wdw),File_records
4070      NEXT Ch
4080    NEXT Wdw
4090    !
4100    DISP
4110  SUBEND
4120  !________________________________________________________________________
4130 Das_1_ad200:SUB Das_1_ad200(@Ad_buff,Window)
4140  !
4150  !This module is the single-card Infotek Systems AD-200 Data Aquisition
4160  !System.  It sets up card, prompts to begin the test, and, if MODE is
4170  !INTERNAL, immediately logs the data; if MODE is EXTERNAL, it awaits the
4180  !external trigger before commencing. After the acquisition is complete it
4190  !checks for errors; if any are present, it posts an ERROR LIST and pauses
4200  !the program.
4210  !
4220  !Inputs:
4230  !    Window   = data logging iteration
```

```
4240 !Outputs:
4250 !    @Ad_buff = pathname to multiplexed (collected) data
4260 !Calls:
4270 !    Ad200_check
4280 !    Start_test
4290 !=========================================================================
4300   OPTION BASE 1
4310   COM /Ad_setup1/ INTEGER Card_no,Dvm_flag,No_cards,No_channels,Max_cards
4320   COM /Ad_setup2/ INTEGER Max_channels,No_windows,Trigger(*)
4330   COM /Ad_setup3/ Duration(*),No_samples(*),Period(*),Sample_rate(*)
4340   COM /Ad_setup4/ Ad_gain(*),Mode$(*),Preset$(*)
4350   COM /Infotek/ INTEGER Ad_addr(*),Code(*),Entry(*),Offset
4360   COM /Test_data/ Labels$(*),Gains(*),Test_time
4370   !-----------------------------------------------------------------------
4380   ALLOCATE Cmd_text$[200],Text$[100]
4390   !
4400   Cd=Card_no                                        !Build command string
4410   Count=No_samples(Window)
4420   Time=Period(Window)
4430   OUTPUT Text$ USING "#,K,8D,K,9D";",COUNT,";Count;",TIME,";Time
4440   Cmd_text$=Preset$(Cd,Window)&Text$
4450 ! PRINT Cmd_text$
4460 ! PRINT
4470   !
4480   ASSIGN @Adc TO Ad_addr(Cd)                        !Init and check setup
4490   OUTPUT @Adc;Cmd_text$
4500   Ad200_check(@Adc,Cd,"in DAS_1_AD200 -- during setup in Card #")
4510   ASSIGN @Adc TO *
4520   !
4530   IF Dvm_flag=0 THEN                                !Initialize ARB GEN
4540     Arb_init(Window)
4550   END IF
4560   !
4570   ASSIGN @Adc_data TO Ad_addr(Cd);WORD              !Are we ready?
4580   Start_test(Test_time,Dvm_flag)
4590   DISP "Logging data with a single Ad_200 card....."
4600   Start=TIMEDATE
4610   TRANSFER @Adc_data TO @Ad_buff;WAIT               !Log data
4620   Stop=TIMEDATE
4630   IF Dvm_flag=0 THEN PRINT "ELAPSE =";Stop-Start
4640   ASSIGN @Adc_data TO *
4650   DISP ""
4660   !
4670   ASSIGN @Adc TO Ad_addr(Cd)                      !Check for logging errors
4680   Ad200_check(@Adc,Cd,"in DAS_1_AD200 -- post logging in Card #")
4690   ASSIGN @Adc TO *
4700   !
4710   DEALLOCATE Cmd_text$,Text$
4720 SUBEND
4730 !________________________________________________________________________
4740 Das_4_ad200:SUB Das_4_ad200(Window,INTEGER Data(*))
4750 !
4760 !Written by..: D. Evans -- Infotek Systems, 1986
4770 !Modified by.: N. Chalk -- GEOTECHnical resources ltd, 1986
4780 !
4790 !This module is the driver for the multi_card AD200 Data Acquisition
4800 !System.  It employs  M68000 machine code to impliment a unique FHS I/O
4810 !routine.  The cards must be slaved from one master, and the master count
4820 !must be set to the total number of samples divided by the number of
4830 !cards.  Each slave must have its count set to 1, and operates in external
```

```
4840 !mode only.
4850 !
4860 !Inputs:
4870 !    Window     = current DAS iteration
4880 !Outputs:
4890 !    Data(*)    = multiplexed raw data array
4900 !Calls:
4910 !    Init_addrs
4920 !    Init_arb
4930 !    Start_test
4940 !===========================================================================
4950   OPTION BASE 1
4960   COM /Ad_setup1/ INTEGER Card_no,Dvm_flag,No_cards,No_channels,Max_cards
4970   COM /Ad_setup2/ INTEGER Max_channels,No_windows,Trigger(*)
4980   COM /Ad_setup3/ Duration(*),No_samples(*),Period(*),Sample_rate(*)
4990   COM /Ad_setup4/ Ad_gain(*),Mode$(*),Preset$(*)
5000   COM /Infotek/ INTEGER Ad_addr(*),Code(*),Entry(*),Offset
5010   COM /Test_data/ Labels$(*),Gains(*),Test_time
5020   !--------------------------------------------------------------------------
5030   ALLOCATE Cmd_text$(Max_cards)[200],Text$[100]
5040   !
5050   FOR Cd=1 TO Max_cards                           !Complete command strings
5060     IF Cd=1 THEN
5070       Count=No_samples(Window)
5080       Time=Period(Window)
5090       OUTPUT Text$ USING "#,K,8D,K,9D";",COUNT ";Count;",TIME ";Time
5100       Cmd_text$(Cd)=Preset$(Cd,Window)&Text$&",STATUS"
5110     ELSE
5120       Cmd_text$(Cd)=Preset$(Cd,Window)&",STATUS"
5130     END IF
5140   NEXT Cd
5150   !
5160   FOR Cd=1 TO Max_cards                           !Initialize cards
5170     ASSIGN @Adc TO Ad_addr(Cd)
5180     OUTPUT @Adc;Cmd_text$(Cd)
5190     Ad200_check(@Adc,Cd,"in DAS_4_ad200 -- during setup in Card #")
5200   NEXT Cd
5210   ASSIGN @Adc TO *
5220   !
5230   IF Dvm_flag=0 THEN                              !Initialize ARB GEN
5240     Arb_init(Window)
5250   END IF
5260   !
5270   Readcode(Code(*),Entry(*),Offset)               !Setup INFOTEK routine
5280   Init_addrs(Ad_addr(*),Code(*),Offset,Data(1,1,1,1),Data(*))
5290   !
5300   Start_test(Test_time,Dvm_flag)                  !Are we ready?
5310   DISP "Logging data using";No_cards;"Ad-200 cards...."
5320   !
5330   FOR Cd=2 TO No_cards                            !Enable slave(s)
5340     Dummy=READIO(Ad_addr(Cd),5)
5350     WRITEIO Ad_addr(Cd),0;0
5360   NEXT Cd
5370   !
5380   Start=TIMEDATE
5390   WRITEIO -9827,READIO(-9827,Code(Entry(No_cards-1)));0
5400   Stop=TIMEDATE
5410   PRINT TABXY(1,19);"
5420   PRINT TABXY(1,19);"ELAPSE = ";(Stop-Start)
5430   !
```

```
5440    Cd=1                                         !Check MASTER card only!!
5450    ASSIGN @Adc TO Ad_addr(Cd)
5460    Ad200_check(@Adc,Cd,"in DAS_4_ad200 -- post logging in Cd #")
5470    ASSIGN @Adc TO *
5480    !
5490    DISP ""
5500    DEALLOCATE Cmd_text$(*),Text$
5510  SUBEND
5520  !____________________________________________________________________
5530 Demultiplexer:SUB Demultiplexer(INTEGER Data(*) BUFFER,Ch_id$(*))
5540  !
5550  !This module takes an buffer array containing multiplexed data and swaps
5560  !rows (data) for columns (channels).  It then transfers each channel to
5570  !its own file by repositioning the "fill pointer" to the beginning of each
5580  !channel.  Rows and columns refer to the original data array, which must
5590  !be a buffer array.
5600  !
5610  !Inputs:
5620  !     Data(*)      = two-dimensional buffer data array to be demultiplexed
5630  !     Ch_id$(*)    = MSU channel list array
5640  !====================================================================
5650    OPTION BASE 1
5660    COM /Demux/ Extant_record,Extant_byte,INTEGER Window
5670    COM /Files_2/ Msus$,Temp_files$(*),Hdr_size
5680    !------------------------------------------------------------------
5690    Columns=SIZE(Data,2)                         !Number of channels
5700    Rows=SIZE(Data,1)                            !Number of samples
5710    Buffsize=0                                   !Current number of samples
5720    Emt=0                                        !Current fill ptr position
5730    !
5740    DISP "Demultiplexing and filing data....."
5750    !
5760    ALLOCATE INTEGER Temp(Rows,Columns)          !Transpose data array
5770    MAT Temp= TRN(Data)
5780    MAT Data= Temp
5790    DEALLOCATE Temp(*)
5800    !
5810    ASSIGN @Data TO BUFFER Data(*)               !Demultiplex data
5820    STATUS @Data,2;Buffsize
5830    FOR I=1 TO Columns
5840      STATUS @Data,5;Emt
5850      Fill=Rows*2+Emt
5860      IF Fill>Buffsize THEN Fill=1
5870      CONTROL @Data,3;Fill
5880      ASSIGN @File TO Ch_id$(I,Window)&Msus$
5890      CONTROL @File,5;Extant_record              !\Set EOF pointers to
5900      CONTROL @File,6;Extant_byte                !/current positions
5910      TRANSFER @Data TO @File;END,WAIT           !Spool data
5920    NEXT I
5930    ASSIGN @Data TO *
5940    !
5950    STATUS @File,5;Extant_record                 !Update EOF pointers
5960    STATUS @File,6;Extant_byte
5970    ASSIGN @File TO *
5980    !
5990    DISP
6000  SUBEND
6010  !____________________________________________________________________
6020 Demux_data:SUB Demux_data
6030  !
```

```
6040 !This driver demultiplexes data stored in a source disk file and restores
6050 !each demultiplexed data channel in its own destination disk file.  If the
6060 !number of channels is one, it simply renames the source file as the
6070 !destination file.
6080 !
6090 !Calls:
6100 !    Build_files
6110 !    Demultiplexer
6120 !==========================================================================
6130   OPTION BASE 1
6140   COM /Ad_setup1/ INTEGER Card_no,Dvm_flag,No_cards,No_channels,Max_cards
6150   COM /Ad_setup2/ INTEGER Max_channels,No_windows,Trigger(*)
6160   COM /Files_1/ Index_file$,Test_hdr$,File_id$(*)
6170   COM /Files_2/ Msus$,Temp_files$(*),Hdr_size
6180   COM /Demux/ Extant_record,Extant_byte,INTEGER Window
6190   COM /Test_data/ Labels$(*),Gains(*),Test_time
6200   !------------------------------------------------------------------------
6210   INTEGER Temp_buff(10000,32) BUFFER
6220   ALLOCATE Ch_id$(No_channels,No_windows)[10]
6230   ALLOCATE Rec_len(No_windows),Last_rec(No_windows)
6240   ALLOCATE Last_rec_bytes(No_windows),File_size(No_windows)
6250   REAL Rows,Columns
6260   INTEGER Samples
6270   !
6280   MAT Ch_id$= ("$")
6290   !
6300   FOR Window=1 TO No_windows                      !Find file size in bytes
6310     ASSIGN @File TO Temp_files$(Window)&Msus$
6320     STATUS @File,4;Rec_len(Window)
6330     STATUS @File,7;Last_rec(Window)
6340     STATUS @File,8;Last_rec_bytes(Window)
6350     ASSIGN @File TO *
6360     File_size(Window)=(Rec_len(Window)*(Last_rec(Window)-1)+(Last_rec_byte
6370   NEXT Window
6380   !
6390   IF No_channels/No_cards=1 THEN                  ! (No demuxing required)
6400     FOR Wdw=1 TO No_windows
6410       FOR Cd=1 TO No_cards
6420         Ch_id$(1,Wdw)=File_id$(Cd,1,Wdw)
6430         RENAME Temp_files$(Wdw)&Msus$ TO Ch_id$(1,Wdw)&Msus$
6440 !       GOSUB Check                               ! <Debugging aid>
6450       NEXT Cd
6460     NEXT Wdw
6470     SUBEXIT
6480   END IF
6490   !
6500   DISP "Setting up channel de-multiplexer."
6510   !
6520   FOR Window=1 TO No_windows                      !Find file size in bytes
6530     ASSIGN @File TO Temp_files$(Window)&Msus$
6540     STATUS @File,4;Rec_len(Window)
6550     STATUS @File,7;Last_rec(Window)
6560     STATUS @File,8;Last_rec_bytes(Window)
6570     ASSIGN @File TO *
6580     File_size(Window)=(Rec_len(Window)*(Last_rec(Window)-1)+(Last_rec_byte
6590   NEXT Window
6600   !
6610   Purge=0                                         !Build channel files
6620   FOR Window=1 TO No_windows
6630     No_file_rec=1+(File_size(Window)/No_channels DIV 256)
```

```
6640      Build_files(No_file_rec,Ch_id$(*))
6650    NEXT Window
6660    !
6670    FOR Window=1 TO No_windows                    !Find max buff length
6680      Rows=SIZE(Temp_buff,1)                      ! (must be < .5 avail mem)
6690      Columns=SIZE(Temp_buff,2)
6700      Rows=MIN(32767,Rows*Columns/No_channels)
6710      !
6720      Total_samples=File_size(Window)/2           !No. of iterations req'd
6730      Samples_per_ch=Total_samples DIV No_channels
6740      N_blocks=1+(Total_samples DIV (Rows*No_channels))
6750      !
6760      Extant_record=1                             !\Init current destination
6770      Extant_byte=1                               !/file record and byte
6780      Current_rec=1                               !\Init current temporary
6790      Current_byte=1                              !/buffer record and byte
6800      !
6810      FOR Block=1 TO N_blocks                     !Jog around the block
6820        Samples=MIN(Rows,Samples_per_ch)          !\Select and set temp
6830        ASSIGN @File TO Temp_files$(Window)&Msus$ !/buff size
6840        IF Block=N_blocks THEN                    ! (If Last block, set
6850          STATUS @File,7;Eof_rec                  ! array size to EOF)
6860          STATUS @File,8;Eof_byte
6870          Bytes_left=256*(Eof_rec-Current_rec)+(Eof_byte-Current_byte)
6880          PRINT "Last block. Bytes left=";Bytes_left     !<<<<<
6890          Samples=Bytes_left/(No_channels*2)
6900        END IF
6910        REDIM Temp_buff(Samples,No_channels)
6920        ASSIGN @Temp TO BUFFER Temp_buff(*)
6930        !
6940        CONTROL @File,5;Current_rec               !Reset file pointers
6950        CONTROL @File,6;Current_byte
6960        !
6970        TRANSFER @File TO @Temp;WAIT              !Upload one block
6980        !
6990        STATUS @File,5;Current_rec                !Save file pointers
7000        STATUS @File,6;Current_byte
7010        ASSIGN @File TO *
7020        ASSIGN @Temp TO *
7030        !
7040        Demultiplexer(Temp_buff(*),Ch_id$(*))    !Demux and file data
7050      NEXT Block
7060      PURGE Temp_files$(Window)&Msus$
7070    NEXT Window
7080    !
7090    DISP ""
7100  ! GOSUB Check                                   ! <Debugging aid>
7110    SUBEXIT
7120    !+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
7130 Check:                                           !Works for files < 32 kB
7140    FOR Wdw=1 TO No_windows
7150      FOR Ch=1 TO No_channels
7160        ALLOCATE INTEGER Indat(INT(File_size(Wdw)/2/No_channels))
7170        ASSIGN @File TO Ch_id$(Ch,Wdw)
7180        ENTER @File;Indat(*)
7190        ASSIGN @File TO *
7200        PRINT Ch_id$(Ch,Wdw);"
";Indat(*)
7210        DEALLOCATE Indat(*)
7220      NEXT Ch
```

```
7230     NEXT Wdw
7240     RETURN
7250   SUBEND
7260   !____________________________________________________________________________
7270 Display:SUB Display(Mode,INTEGER Data(*))
7280   !
7290   !This module builds the data array Temp(*) in either voltage or raw data,
7300   !depending on the value of Mode, and outputs the data to the CRT screen.
7310   !
7320   !Inputs:
7330   !     Data(*)      = raw data
7340   !     Mode         = 0 for voltage display, 1 for raw data display
7350   !============================================================================
7360     OPTION BASE 1
7370     COM /Ad_setup1/ INTEGER Card_no,Dvm_flag,No_cards,No_channels,Max_cards
7380     COM /Ad_setup2/ INTEGER Max_channels,No_windows,Trigger(*)
7390     COM /Ad_setup4/ Ad_gain(*),Mode$(*),Preset$(*)
7400     COM /Test_data/ Labels$(*),Gains(*),Test_time
7410     !--------------------------------------------------------------------------
7420     ALLOCATE Temp(No_channels),Tx_labels$(No_channels)[10]
7430     INTEGER Element,Pass,Label,Chan,Tag
7440     !
7450     Chan=0                                            !Build data/label arrays
7460     FOR Ch=1 TO No_channels/No_cards
7470       FOR Cd=1 TO No_cards
7480         Chan=Chan+1
7490         Tx_labels$(Chan)=Labels$(Cd,Ch,1)
7500         SELECT Mode
7510         CASE 0                                        ! (Volts)
7520           Temp(Chan)=Data(1,1,Ch,Cd)*Gains(Cd,Ch,1)
7530         CASE 1                                        ! (Raw data)
7540           Temp(Chan)=Data(1,1,Ch,Cd)
7550         CASE 2                                        ! (Eng data)
7560           Space=9-(LEN(Tx_labels$(Chan))+LEN(Labels$(Cd,Ch,3)))
7570           Tx_labels$(Chan)=Tx_labels$(Chan)&RPT$(" ",Space)&Labels$(Cd,Ch,3)
7580           Temp(Chan)=Gains(Cd,Ch,2)*((Data(1,1,Ch,Cd)*Gains(Cd,Ch,1))-Gains(
7590         END SELECT
7600       NEXT Cd
7610     NEXT Ch
7620     !
7630     PRINT TABXY(1,3);                                 !Initialize cursor
7640     !
7650     Pass=0                                            !Build CRT DVM display
7660     Label=0
7670     Chan=0
7680     FOR Ch=1 TO No_channels STEP 8
7690       FOR Tag=1 TO MIN(8,No_channels-8*Pass)
7700         Label=Label+1
7710         PRINT USING "9A,X,$";Tx_labels$(Label)
7720       NEXT Tag
7730       IF Tag<=8 THEN OUTPUT CRT;"
";
7740       FOR Reading=1 TO MIN(8,No_channels-8*Pass)
7750         Chan=Chan+1
7760         SELECT Mode
7770         CASE 0                                        ! (Volts)
7780           PRINT USING "K,3D.5D,K,X,$";CHR$(129);Temp(Chan);CHR$(128)
7790         CASE 1                                        ! (Raw data)
7800           PRINT USING "K,3A,6D,K,X,$";CHR$(129);"RAW";Temp(Chan);CHR$(128)
7810         CASE 2
```

```
7820          PRINT USING "K,A,SD.2D,K,X,#";CHR$(129);"E";Temp(Chan);CHR$(128)
7830        END SELECT
7840      NEXT Reading
7850      Pass=Pass+1
7860    NEXT Ch
7870    !
7880    DEALLOCATE Temp(*),Tx_labels$(*)
7890  SUBEND
7900  !_______________________________________________________________________
7910 Download_array:SUB Download_array(INTEGER Array(*),File$,Msus$)
7920  !
7930  !This module store a memory array in a temporary disk file.  It
7940  !calculates the size of the file needed, creates the file, resets the
7950  !buffer pointers, and transfers the data, in FHS I/O mode, to the MSU.
7960  !
7970  !Inputs:
7980  !    Array(*) = source memory array
7990  !    File$    = destination disk file
8000  !    Msus$    = target disk identifier
8010  !=======================================================================
8020    OPTION BASE 1
8030    INTEGER Temp(3,32767) BUFFER
8040    !
8050    DISP "Downloading Ad-200 array to a temporary file."
8060    !
8070    N_channels=SIZE(Array,1)                     !Find file size
8080    N_samples=SIZE(Array,2)
8090    N_cards=SIZE(Array,3)
8100    N_groups=SIZE(Array,4)
8110    N_words=N_channels*N_samples*N_cards*N_groups
8120    File_size=((N_words*2) DIV 256)+1
8130    !
8140    ON ERROR RECOVER Ok                          !Setup file and path
8150    PURGE File$&Msus$
8160 Ok:OFF ERROR
8170    CREATE BDAT File$&Msus$,File_size
8180    !
8190    ASSIGN @File TO File$&Msus$                  !Download data
8200    OUTPUT @File;Array(*)
8210    ASSIGN @File TO *
8220    !
8230    DISP ""
8240   !GOSUB Print                                  !<Debugging aid>
8250    SUBEXIT
8260    !++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
8270 Print:REDIM Temp(3,N_words/3)
8280    ASSIGN @File TO File$
8290    ENTER @File USING "#,W";Temp(*)
8300    PRINT Temp(*)
8310    ASSIGN @File TO *
8320    RETURN
8330  SUBEND
8340  !_______________________________________________________________________
8350 Download_buffer:SUB Download_buffer(@Buff,File$,Msus$)
8360  !
8370  !This module store a memory buffer in a temporary disk file.  It
8380  !calculates the size of the file needed, creates the file, resets the
8390  !buffer pointers, and transfers the data in FHS mode.
8400  !
8410  !Inputs:
```

```
8420  !    @Buff = source memory buffer
8430  !    File$ = destination disk file
8440  !    Msus$ = target disk identifier
8450  !=====================================================================
8460    OPTION BASE 1
8470    INTEGER Temp(32767) BUFFER
8480    !
8490    DISP "Downloading Ad-200 buffer to a temporary file."
8500    !
8510    STATUS @Buff,2;Buff_bytes                         !Calculate destination
8520    File_size=(Buff_bytes DIV 256)+1                  !file size
8530    !
8540    ON ERROR RECOVER Ok                               !Create destination file
8550    PURGE File$&Msus$
8560 Ok:OFF ERROR
8570    CREATE BDAT File$&Msus$,File_size
8580    !
8590    ASSIGN @File TO File$&Msus$                       !Download data
8600    CONTROL @Buff,4;Buff_bytes
8610    TRANSFER @Buff TO @File;END,WAIT
8620    ASSIGN @File TO *
8630    !
8640    DISP ""
8650   !GOSUB Print                                       !<Debugging aid>
8660    SUBEXIT
8670    !+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
8680 Print:REDIM Temp(Buff_bytes/2)
8690    ASSIGN @File TO File$&Msus$
8700    ENTER @File;Temp(*)
8710    PRINT Temp(*)
8720    ASSIGN @File TO *
8730    RETURN
8740  SUBEND
8750  !_____________________________________________________________________
8760 Disk_needed:DEF FNDisk_needed
8770  !
8780  !This function returns the amount of disk space, in words, needed. The
8790  !times 2 factor in the output statement takes into account the space
8800  !needed for the temporary storage data array(s) utilized by the demuxing
8810  !routine.
8820  !=====================================================================
8830    OPTION BASE 1
8840    COM /Ad_setup1/ INTEGER Card_no,Dvm_flag,No_cards,No_channels,Max_cards
8850    COM /Ad_setup2/ INTEGER Max_channels,No_windows,Trigger(*)
8860    COM /Ad_setup3/ Duration(*),No_samples(*),Period(*),Sample_rate(*)
8870    COM /Files_2/ Msus$,Temp_files$(*),Hdr_size
8880    !---------------------------------------------------------------------
8890    REAL Index_words,Words
8900    !
8910    Words=0
8920    FOR Window=1 TO No_windows
8930      Words=Words+(No_samples(Window)*No_cards)
8940    NEXT Window
8950    !
8960    Index_words=Hdr_size*256/2
8970    RETURN (Index_words+Words*2)
8980  FNEND
8990  !_____________________________________________________________________
9000 Disk_space:DEF FNDisk_space(Msus$)
9010  !
```

```
9020  !This function returns the amount of disk space remaining, in words.
9030  !
9040  !Inputs:
9050  !    Msus$ = disk identifier
9060  !===========================================================================
9070    OPTION BASE 1
9080    ALLOCATE Catstring$(4)[80]
9090    CAT Msus$ TO Catstring$(*)
9100    RETURN (256.*VAL(Catstring$(4)[17])) DIV 2
9110  FNEND
9120  !___________________________________________________________________________
9130 Purge_files:SUB Purge_files(Purge)
9140  !
9150  !This module either automatically purges a file or checks if it is safe to
9160  !purge a file.  In the check mode, once the operator deems it okay to
9170  !purge a file, it assumes all subsequent files encountered are to be
9180  !purged as well, unless otherwise directed.  If the error which caused
9190  !branch was not a "duplicate file error", it assumes the error is fatal,
9200  !prints the fatal error message, and stops.
9210  !The ON ERROR which calls this module cannot do so directly; it must pass
9220  !contol to a label which then calls it.  The line following the call
9230  !statement must then branch back to the statement that caused the error.
9240  !
9250  !Inputs:
9260  !    Purge = "0" for conditional purge, "1" for automatic purge
9270  !===========================================================================
9280    OPTION BASE 1
9290    COM /Ad_setup2/ INTEGER Max_channels,No_windows,Trigger(*)
9300    COM /Files_1/ Index_file$,Test_hdr$,File_id$(*)
9310    COM /Files_2/ Msus$,Temp_files$(*),Hdr_size
9320    !-------------------------------------------------------------------------
9330    ALLOCATE Prefix$[6],Purge_array$(Max_channels+1)[80]
9340    INTEGER Ch,Files,Window
9350    !
9360    Files=0                                         !Check for existing files
9370    Prefix$=Test_hdr$[1,5]
9380    CAT Msus$ TO Purge_array$(*);SELECT Prefix$,COUNT Files,NO HEADER
9390    !
9400    IF Files<>0 THEN
9410      SELECT Purge
9420      CASE 0
9430        PRINT
9440        PRINT "Extraneous file list: ";
9450        ON ERROR GOTO Done
9460        FOR Ch=1 TO Files STEP 2
9470          PRINT TAB(23);Purge_array$(Ch)[1,10],Purge_array$(Ch+1)[1,10]
9480        NEXT Ch
9490 Done:                                               !
9500        PRINT
9510        DISP CHR$(129)
9520        Ans$=""
9530        INPUT " Delete extraneous file(s)? (Y/N) ",Ans$
9540        DISP CHR$(128)
9550        IF UPC$(Ans$[1])="Y" THEN
9560          GOTO Delete_files
9570        ELSE
9580          STOP
9590        END IF
9600      CASE 1
9610        GOTO Delete_files
```

```
9620      END SELECT
9630      !
9640 Delete_files:                                   !
9650      PRINT "These files have been purged!!!"
9660      FOR Window=1 TO No_windows
9670        FOR Ch=1 TO Files
9680          PURGE Purge_array$(Ch)[1,10]&Msus$
9690        NEXT Ch
9700      NEXT Window
9710    END IF
9720    !
9730 Quit:                                           !
9740    DEALLOCATE Purge_array$(*)
9750  SUBEND
9760  !_______________________________________________________________________
9770 Init_das_cmd:SUB Init_das_cmd
9780  !
9790  !This module checks if the number of AD200 cards is valid, selects the
9800  !TRIGGER mode, builds the CMG strings and preliminary command text
9810  !strings for Das_1_ad200 (single-card DAS) and Das_4_ad200 (multi-card
9820  !DAS) subprogrammes.
9830  !=======================================================================
9840    OPTION BASE 1
9850    COM /Ad_setup1/ INTEGER Card_no,Dvm_flag,No_cards,No_channels,Max_cards
9860    COM /Ad_setup2/ INTEGER Max_channels,No_windows,Trigger(*)
9870    COM /Ad_setup3/ Duration(*),No_samples(*),Period(*),Sample_rate(*)
9880    COM /Ad_setup4/ Ad_gain(*),Mode$(*),Preset$(*)
9890    COM /Infotek/ INTEGER Ad_addr(*),Code(*),Entry(*),Offset
9900    !---------------------------------------------------------------------
9910    ALLOCATE Cmg$(No_cards)[100],Trigger$(No_windows)[10]
9920    !
9930    DISP "Initializing the Ad-200 card(s)."
9940    WAIT .5
9950    !
9960    FOR Window=1 TO No_windows                   !Select TRIGGER mode
9970      SELECT Trigger(Window)
9980      CASE 0
9990        Trigger$(Window)="INTERNAL"
10000     CASE 1
10010       Trigger$(Window)="EXTERNAL"
10020     CASE ELSE
10030       PRINT "Eek!!  AD200 TRIGGER mode neither INTERNAL nor EXTERNAL!"
10040       PAUSE
10050     END SELECT
10060   NEXT Window
10070   !
10080   FOR Cd=1 TO No_cards                         !Build channel, mode, gain
10090     FOR Ch=1 TO No_channels/No_cards           !(CMG) string(s)
10100       Cmg$(Cd)=Cmg$(Cd)&VAL$(Ch)&Mode$(Cd,Ch)&VAL$(Ad_gain(Cd,Ch,1))&" "
10110     NEXT Ch
10120   NEXT Cd
10130   !
10140   FOR Window=1 TO No_windows                   !Build command strings
10150     FOR Cd=1 TO No_cards
10160       SELECT Cd
10170       CASE 1
10180         Preset$(Cd,Window)="RESET,DELAYON,HOLDOFF,"&Trigger$(Window)&",SEL
10190       CASE 2 TO 4
10200         Preset$(Cd,Window)="RESET,DELAYOFF,HOLDOFF,EXTERNAL,SELECT "&Cmg$(
10210       END SELECT
```

```
10220     NEXT Cd
10230   NEXT Window
10240   !
10250   DISP ""
10260   DEALLOCATE Cmg$(*),Trigger$(*)
10270 SUBEND
10280 !____________________________________________________________________
10290 Init_addrs:SUB Init_addrs(INTEGER Ad_addr(*),Code(*),Offset,Data1,Data(*))
10300 !
10310 !Written by..: D. Evans -- Infotek Systems, 1986
10320 !Modified by.: N. Chalk -- GEOTECHnical resources ltd, 1986
10330 !
10340 !This module initializes the data section of the code array. Data1 should
10350 !be the first element in the array Data(*).
10360 !
10370 !Inputs:
10380 !    Ad_addr(*) = AD_200 system addresses
10390 !    Code(*)    = M68000 machine code DAS
10400 !    Offset     = points to registers in code data statements
10410 !    Data1      = contains the memory address of the array Data(*)
10420 !    Data(*)    = integer data array
10430 !=====================================================================
10440   OPTION BASE 1
10450   ALLOCATE Cd_lo(4),Cd_hi(4)
10460   !
10470   N_cards=SIZE(Ad_addr,1)
10480   !
10490   Pctl_hi=0+Offset                                  !Set pointers to register
10500   Pctl_lo=1+Offset                                  !addresses
10510   Cd_hi(1)=2+Offset
10520   Cd_lo(1)=3+Offset
10530   Cd_hi(2)=4+Offset
10540   Cd_lo(2)=5+Offset
10550   Cd_hi(3)=6+Offset
10560   Cd_lo(3)=7+Offset
10570   Cd_hi(4)=8+Offset
10580   Cd_lo(4)=9+Offset
10590   Array_hi=10+Offset
10600   Array_lo=11+Offset
10610   Size_hi=12+Offset
10620   Size_lo=13+Offset
10630   !
10640   Addr_sc=Ad_addr(1)*65536.+DVAL("600000",16)   !Initialize the master
10650   T$=DVAL$(Addr_sc,16)                              !card registers
10660   Code(Pctl_hi)=IVAL(T$[1;4],16)
10670   Code(Pctl_lo)=IVAL(T$[5;4],16)
10680   Code(Cd_hi(1))=Code(Pctl_hi)
10690   Code(Cd_lo(1))=Code(Pctl_lo)+4
10700   !
10710   FOR Cd=2 TO N_cards                              !Init slave card registers
10720     Addr_sc=Ad_addr(Cd)*65536.+DVAL("600004",16)
10730     T$=DVAL$(Addr_sc,16)
10740     Code(Cd_hi(Cd))=IVAL(T$[1;4],16)
10750     Code(Cd_lo(Cd))=IVAL(T$[5;4],16)
10760   NEXT Cd
10770   !
10780   Addr_buf=READIO(-9827,Data1)                      !Find array memory
10790   T$=DVAL$(Addr_buf,16)                             !location and initialize
10800   Code(Array_hi)=IVAL(T$[1;4],16)                   !the address register
10810   Code(Array_lo)=IVAL(T$[5;4],16)
```

```
10820   !
10830   Size_buf=1                                    !Find array size
10840   FOR Dim=1 TO RANK(Data)
10850     Size_buf=Size_buf*SIZE(Data,Dim)
10860   NEXT Dim
10870   Size_buf=1.*DVAL((DVAL$(Size_buf DIV N_cards,16)),16)*N_cards
10880   !
10890   T$=DVAL$(Size_buf,16)                         !Initialize the array size
10900   Code(Size_hi)=IVAL(T$[1;4],16)                !register
10910   Code(Size_lo)=IVAL(T$[5;4],16)
10920   !
10930   DEALLOCATE Cd_lo(*),Cd_hi(*)
10940 SUBEND
10950 !_________________________________________________________________________
10960 Setup_index:SUB Setup_index
10970 !
10980 !This module checks if the entered test series is new or current and if
10990 !the entered test number is sequential, valid, and/or a duplication.
11000 !==================-=======================================================
11010   OPTION BASE 1
11020   COM /Files_1/ Index_file$,Test_hdr$[10],File_id$(*)
11030   COM /Files_2/ Msus$,Temp_files$(*),Hdr_size
11040   !-----------------------------------------------------------------------
11050   ALLOCATE Index_desc$[80],Id$[10],String$(2)[80],Test_id$(99)[10]
11060   ALLOCATE Test_time(99),INTEGER Test_status(99)
11070   !
11080   PRINTER IS CRT
11090   !
11100 Index:                                        !Test series identifier
11110   Id$="PBT"                      !}}}}}}
11120   REPEAT
11130     DISP CHR$(129)
11140     INPUT " Enter TEST SERIES NAME. (1 to 3 alpha-numeric characters) ",Id
11150     DISP CHR$(128)
11160     IF Id$="" THEN BEEP
11170   UNTIL Id$<>""
11180   !
11190   SELECT LEN(Id$)                               !Build index file name
11200   CASE <3
11210     Index_file$=UPC$(Id$)&RPT$("_",3-LEN(Id$))&"_INDEX"
11220   CASE =3
11230     Index_file$=UPC$(Id$[1,3])&"_INDEX"
11240   CASE >3
11250     GOTO Index
11260   END SELECT
11270   !
11280   DISP "Searching for existing test series index file ";Index_file$
11290   CAT Msus$ TO String$(*);SELECT Index_file$,COUNT Number,NO HEADER
11300   IF Number=0 THEN
11310     GOSUB Setup_new_index
11320   END IF
11330   !
11340 New_test:                                     !Check for previous tests
11350   ASSIGN @File TO Index_file$&Msus$
11360   ON ERROR GOTO Index_error
11370   ENTER @File;Index_desc$
11380   OFF ERROR
11390   PRINT Index_desc$
11400   ALLOCATE Status$(99)[2],Time$(99)[8],Date$(99)[12]
11410   ON END @File RECOVER Print_list
```

```
11420   Test=0
11430   LOOP
11440     Test=Test+1
11450     ENTER @File;Test_id$(Test);Test_time(Test);Test_status(Test)
11460     SELECT Test_status(Test)
11470     CASE 0
11480       Status$(Test)="OK"
11490     CASE 1
11500       Status$(Test)="NG"
11510     END SELECT
11520     Time$(Test)=TIME$(Test_time(Test))
11530     Date$(Test)=DATE$(Test_time(Test))
11540   END LOOP
11550   !
11560 Print_list:                                     !
11570   OFF END @File
11580   ASSIGN @File TO *
11590   No_tests=Test-1
11600   IF No_tests<>0 THEN
11610     PRINT RPT$("-",46)
11620     FOR Test=1 TO No_tests
11630       PRINT Test_id$(Test);"        ";Time$(Test);"     ";
11640       PRINT Date$(Test);"     ";Status$(Test)
11650     NEXT Test
11660     PRINT RPT$("-",46)
11670   END IF
11680   DEALLOCATE Status$(*),Time$(*),Date$(*)
11690   PRINT "Number of tests so far: ";No_tests
11700   !
11710 Enter_test:                                     !Enter new test or abort
11720   REPEAT
11730     Test_no=-999
11740     DISP CHR$(129)
11750     INPUT " Enter Test number. (1 < TEST > 99 or 0 to abort) ",Test_no
11760     DISP CHR$(128)
11770     IF Test_no=0 THEN GOTO Abort_entry
11780     IF Test_no=-999 THEN
11790       BEEP
11800       GOTO Enter_test
11810     END IF
11820   UNTIL Test_no>0 AND Test_no<99
11830   !
11840   IF Test_no<>No_tests+1 THEN                   !Check if it's valid
11850     BEEP
11860     PRINT
11870     PRINT "WARNING!!  This test number does not sequentially follow"
11880     PRINT "           the last recorded test number."
11890     DISP CHR$(129)
11900     INPUT " Is this OK? (y/n) ",Ans$
11910     DISP CHR$(128)
11920     IF UPC$(Ans$[1,1])<>"Y" THEN GOTO Enter_test
11930   END IF
11940   !
11950   SELECT Test_no                                !Build test header name
11960   CASE <10
11970     Test_hdr$=Index_file$[1,3]&"0"&VAL$(Test_no)&"_HDR"
11980   CASE 10 TO 99
11990     Test_hdr$=Index_file$[1,3]&VAL$(Test_no)&"_HDR"
12000   END SELECT
12010   !
```

```
12020   FOR Test=1 TO No_tests                           !Check for duplicate test
12030     IF Test_id$(Test)=Test_hdr$ THEN GOTO Err_dup_test_no
12040   NEXT Test
12050   !
12060   DEALLOCATE Index_desc$,String$(*),Test_id$(*)
12070   DEALLOCATE Test_status(*),Test_time(*)
12080   SUBEXIT
12090   !++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
12100 Abort_entry:                                           !Stop test routine
12110   BEEP
12120   PRINT TABXY(1,7);CHR$(129);" TEST ABORTED BY OPERATOR. ";CHR$(128)
12130   STOP
12140   !
12150 Err_dup_test_no:                                       !
12160   PRINT
12170   PRINT "CANNOT CONTINUE!!!"
12180   PRINT "Duplicate test detected -- INDEX: ";Index_file$;", HEADER: ";Test
12190   PAUSE
12200   !
12210 Index_error:                                           !
12220   Ans$="n"
12230   DISP CHR$(129)
12240   INPUT " Empty index found. Continue? (Y/N) ",Ans$
12250   DISP CHR$(128)
12260   ASSIGN @File TO *
12270   IF UPC$(Ans$[1])<>"Y" THEN Abort_entry
12280   PURGE Index_file$&Msus$
12290   GOTO Setup_new_index
12300   !
12310 Setup_new_index:                                       !New index routine
12320   PRINT TABXY(1,19);"INDEX file ";CHR$(129);" "&Index_file$&" ";CHR$(128);
12330   BEEP
12340   BEEP
12350   DISP CHR$(129)
12360   Ans$="n"
12370   INPUT " CREATE new test series INDEX file? (Y/N) ",Ans$
12380   IF UPC$(Ans$[1])<>"Y" THEN Abort_entry
12390 Description:                                           !
12400   BEEP
12410   INPUT " Enter a one line description of the new test series. ",Index_des
12420   IF Index_desc$=" " THEN Description
12430   PRINT TABXY(1,18);"New test series descriptor:"
12440   PRINT TABXY(1,19);RPT$(" ",80);TABXY(1,19);Index_desc$
12450   Ans$="n"
12460   INPUT " Descriptor Ok? (Y/N) ",Ans$
12470   IF UPC$(Ans$[1])<>"Y" THEN Description
12480   PRINT TABXY(1,17);"New TEST SERIES INDEX file is ";CHR$(129);Index_file$
12490   Ans$="n"
12500   INPUT " Ok to create new file? (Y/N) ",Ans$
12510   IF UPC$(Ans$[1]   "Y" THEN Abort_entry
12520   DISP CHR$(128)
12530   CREATE BDAT Index_file$&Msus$,3
12540   ASSIGN @File TO Index_file$&Msus$
12550   OUTPUT @File;Index_desc$
12560   ASSIGN @File TO *
12570   RETURN
12580 SUBEND
12590 !_____________________________________________________________________
12600 Read_header:SUB Read_header
12610 !
```

```
12620 !This module is a debugging tool; it displays the contents of the file
12630 !test_hdr$.
12640 !=========================================================================
12650   OPTION BASE 1
12660   COM /Ad_setup1/ INTEGER Card_no,Dvm_flag,No_cards,No_channels,Max_cards
12670   COM /Ad_setup2/ INTEGER Max_channels,No_windows,Trigger(*)
12680   COM /Ad_setup3/ Duration(*),No_samples(*),Period(*),Sample_rate(*)
12690   COM /Ad_setup4/ Ad_gain(*),Mode$(*),Preset$(*)
12700   COM /Files_1/ Index_file$,Test_hdr$[10],File_id$(*)
12710   COM /Files_2/ Msus$,Temp_files$(*),Hdr_size
12720   COM /Test_data/ Labels$(*),Gains(*),Test_time
12730   !-----------------------------------------------------------------------
12740   MAT Labels$= ("*")
12750   MAT Mode$= ("*")
12760   MAT Ad_gain= (0)
12770   MAT Gains= (0)
12780   !
12790   ASSIGN @Index TO Test_hdr$&Msus$
12800   ENTER @Index;No_windows
12810   ENTER @Index;No_channels
12820   ENTER @Index;Duration(*)
12830   ENTER @Index;Sample_rate(*)
12840   ENTER @Index;Labels$(*)
12850   ENTER @Index;Mode$(*)
12860   ENTER @Index;Ad_gain(*)
12870   ENTER @Index;Gains(*)
12880   ASSIGN @Index TO *
12890   !
12900   PRINT "No. of time windows=";No_windows
12910   PRINT "No. of channels=";No_channels
12920   PRINT "Durations=";Duration(*)
12930   PRINT "Sample frequencies=";Sample_rate(*)
12940   PRINT Labels$(*)
12950   PRINT Mode$(*)
12960   PRINT Ad_gain(*)
12970   PRINT Gains(*)
12980   PAUSE
12990 SUBEND
13000 !_________________________________________________________________________
13010 Read_index:SUB Read_index
13020 !
13030 !This module is a debugging aid.
13040 !=========================================================================
13050   OPTION BASE 1
13060   COM /Files_1/ Index_file$,Test_hdr$[10],File_id$(*)
13070   COM /Files_2/ Msus$,Temp_files$(*),Hdr_size
13080   !-----------------------------------------------------------------------
13090   ALLOCATE Test_id$(99)[5],Test_time(99),INTEGER Test_status(99)
13100   !
13110   ASSIGN @File TO Index_file$&Msus$
13120   ON END @File RECOVER End_file
13130   ENTER @File;Index_desc$
13140   PRINT Index_desc$
13150   !
13160   I=0
13170   LOOP
13180     I=I+1
13190     ENTER @File;Test_id$(I);Test_time(I);Test_status(I)
13200     PRINT Test_id$(I),TIME$(Test_time(I)),DATE$(Test_time(I)),Test_status(
13210   END LOOP
```

```
13220   !
13230 End_file:                                               !
13240   OFF END @File
13250   ASSIGN @File TO *
13260   PRINT "End of site index file"
13270 SUBEND
13280 !_________________________________________________________________________
13290 Readcode:SUB Readcode(INTEGER Code(*),Entry_offsets(*),Data_offset)
13300 !
13310 !Written by D. Evans   Infotek Systems, 1986
13320 !Modified by N. Chalk  GEOTECHnical Resources Limited, 1986
13330 !
13340 !This module initialize the code array, entry points array, and data
13350 !offsets.  There are three entry points into the code, for 2, 3, and 4
13360 !cards respectively.
13370 !
13380 !Outputs:
13390 !    Code(*)           = M68000 machine code DAS
13400 !    Entry_offsets(*) = entry points for 2 to 4 slave cards in Code(*)
13410 !    Data_offset      = points to registers
13420 !=========================================================================
13430   RESTORE
13440   READ Hex$                                          !Read position of pointers
13450   Data_offset=IVAL(Hex$,16)/2                        !in code
13460   !
13470   FOR I=1 TO 3                                       !Read offsets into code
13480     READ Hex$                                        !for 2 to 4 cards
13490     Entry_offsets(I)=IVAL(Hex$,16)/2
13500   NEXT I
13510   !
13520   FOR I=0 TO Data_offset+12                          !Read machine code into
13530     READ Hex$                                        !array Code(*)
13540     Code(I)=IVAL(Hex$,16)
13550   NEXT I
13560   SUBEXIT
13570   !+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
13580   DATA   00A2       ! load_addr  dc.w       pctl_flag_pt-start2
13590   !
13600   DATA   0000       !            dc.w       start2
13610   DATA   0030       !            dc.w       start3-start2
13620   DATA   0066       !            dc.w       start4-start2
13630   !
13640   DATA   207A,00A0  ! start2     movea.l    pctl_flag_pt,a0
13650   DATA   227A,00A0  !            movea.l    card0_data_pt,a1
13660   DATA   247A,00A0  !            movea.l    card1_data_pt,a2
13670   DATA   2A7A,00A8  !            movea.l    array_pt,a5
13680   DATA   203A,00A8  !            move.l     size,d0
13690   DATA   4E71,4E71  !            nop,nop
13700   DATA   4E71,4E71  !            nop,nop
13710   DATA   4A51       !            tst        (a1)
13720   DATA   1081       ! loop2      move.b     d1,(a0)
13730   DATA   0810,0000  ! wait2      btst       #0,(a0)
13740   DATA   67FA       !            beq.s      wait2
13750   DATA   3AD1       !            move.w     (a1),(a5)+
13760   DATA   3AD2       !            move.w     (a2),(a5)+
13770   DATA   5580       !            subq.l     #2,d0
13780   DATA   6EF0       !            bgt loop2
13790   DATA   4E75       !            rts
13800   !
13810  .DATA   207A,0070  ! start3     movea.l    pctl_flag_pt,a0
```

```
13820  DATA  227A,0070 !              movea.l     card0_data_pt,a1
13830  DATA  247A,0070 !              movea.l     card1_data_pt,a2
13840  DATA  267A,0070 !              movea.l     card2_data_pt,a3
13850  DATA  2A7A,0074 !              movea.l     array_pt,a5
13860  DATA  203A,0074 !              move.l      size,d0
13870  DATA  4E71,4E71 !              nop,nop
13880  DATA  4E71,4E71 !              nop,nop
13890  DATA  4A51      !              tst         (a1)
13900  DATA  1081      ! loop3        move.b      d1,(a0)
13910  DATA  0810,0000 ! wait3        btst        #0,(a0)
13920  DATA  67FA      !              beq.s       wait3
13930  DATA  3AD1      !              move.w      (a1),(a5)+
13940  DATA  3AD2      !              move.w      (a2),(a5)+
13950  DATA  3AD3      !              move.w      (a3),(a5)+
13960  DATA  5780      !              subq.l      #3,d0
13970  DATA  6EEE      !              bgt loop3
13980  DATA  4E75      !              rts
13990   !
14000  DATA  207A,003A ! start4       movea.l     pctl_flag_pt,a0
14010  DATA  227A,003A !              movea.l     card0_data_pt,a1
14020  DATA  247A,003A !              movea.l     card1_data_pt,a2
14030  DATA  267A,003A !              movea.l     card2_data_pt,a3
14040  DATA  287A,003A !              movea.l     card3_data_pt,a4
14050  DATA  2A7A,003A !              movea.l     array_pt,a5
14060  DATA  203A,003A !              move.l      size,d0
14070  DATA  4E71,4E71 !              nop,nop
14080  DATA  4E71,4E71 !              nop,nop
14090  DATA  4A51      !              tst         (a1)
14100  DATA  1081      ! loop4        move.b      d1,(a0)
14110  DATA  0810,0000 ! wait4        btst        #0,(a0)
14120  DATA  67FA      !              beq.s       wait4
14130  DATA  3AD1      !              move.w      (a1),(a5)+
14140  DATA  3AD2      !              move.w      (a2),(a5)+
14150  DATA  3AD3      !              move.w      (a3),(a5)+
14160  DATA  3AD4      !              move.w      (a4),(a5)+
14170  DATA  5980      !              subq.l      #4,d0
14180  DATA  6EEC      !              bgt loop4
14190  DATA  4E75      !              rts
14200   !
14210  DATA  0000,0000 ! pctl_flag_pt     dc.l        0
14220  DATA  0000,0000 ! card0_data_pt    dc.l        0
14230  DATA  0000,0000 ! card1_data_pt    dc.l        0
14240  DATA  0000,0000 ! card2_data_pt    dc.l        0
14250  DATA  0000,0000 ! card3_data_pt    dc.l        0
14260  DATA  0000,0000 ! array_pt         dc.l        0
14270  DATA  0000,0000 ! size             dc.l        0
14280 SUBEND
14290 !______________________________________________________________
14300 Setup_table:SUB Setup_table
14310 !
14320 !This module contains information, entered by the operator,  which is used
14330 !to setup the current test.  It is divided into four major blocks: the
14340 !first two are for data entry, and the last two do the actual setup and
14350 !checks.  The blocks are:
14360 !     1. basic test information;
14370 !     2. transducer data;
14380 !     3. operational checks and setup;
14390 !     4. AD-200 calculations.
14400 !If an error is detected during the setup operation, the error is posted
14410 !and the process terminated.
```

```
14420 !===========================================================================
14430   OPTION BASE 1
14440   COM /Ad_setup1/ INTEGER Card_no,Dvm_flag,No_cards,No_channels,Max_cards
14450   COM /Ad_setup2/ INTEGER Max_channels,No_windows,Trigger(*)
14460   COM /Ad_setup3/ Duration(*),No_samples(*),Period(*),Sample_rate(*)
14470   COM /Ad_setup4/ Ad_gain(*),Mode$(*),Preset$(*)
14480   COM /Files_1/ Index_file$,Test_hdr$[10],File_id$(*)
14490   COM /Files_2/ Msus$,Temp_files$(*),Hdr_size
14500   COM /Test_data/ Labels$(*),Gains(*),Test_time
14510   !-------------------------------------------------------------------------
14520   ALLOCATE Ch_id$(No_channels)[4],Ch_mode$(No_channels)[1]
14530   ALLOCATE Eng_units$(No_channels)[10],Serial$(No_channels)[10]
14540   ALLOCATE Card_channel(No_channels),Card_num(No_channels)
14550   ALLOCATE Ex_gain(No_channels),Hw_gain(No_channels),Sw_gain(No_channels)
14560   ALLOCATE Tx_gain(No_channels),Tx_offset(No_channels)
14570   !
14580   DISP "Reading Transducer and A/D setup data."
14590   !
14600   IF No_cards<1 OR No_cards>Max_cards THEN      !Check number of cards
14610     PRINT TABXY(1,19);"Eek!!  Maximum number of AD200 cards =";Max_cards
14620     BEEP
14630     PAUSE
14640   END IF
14650   !
14660 Transducers:!~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~!
14670   !This table contains setup information for the AD-200 ADC cards and    !
14680   !tranducer descriptions, constants, and serial numbers. Transducers     !
14690   !not in use must be commented out.                                      !
14700   !                                                                       !
14710   !SW gn = AD-200 S/W gain = 1, 2, 5, 10                                  !
14720   !HW gn = AD-200 H/W gain = 1, 4, 10                                     !
14730   !Ex gn = External gain   = gain in input (eg voltage divider)           !
14740   !~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~!
14750 Card1:!
14760   !-----|--|--|--|--|----|--------|--------|-------|------|---------|
14770   !Card |Ch|SW|HW|Ex|Mode| Gain   | Offset | Units |  Ch  | Serial  |
14780   ! no. |no|gn|gn|gn|    |(eng/V)|  (V)   | (/V)  |  Id  | Number  |
14790   !-----|--|--|--|--|----|--------|--------|-------|------|---------|
14800   DATA 1, 1, 1, 1, 1, "S",  107.29, 2.7124,   "mm", "BD1",  "A33380"
14810   DATA 1, 2, 1, 1, 1, "S",  107.42, 2.0726,   "mm", "BD2",  "A22090"
14820   DATA 1, 3, 1, 1, 1, "S",  107.42, 2.3608,   "mm", "BD3",  "A22091"
14830   DATA 1, 4, 1, 1, 1, "S",  6.8529, 0.0879,  "MPa","APR1",    "5817"
14840   DATA 1, 5, 1, 1, 1, "S",  6.8586, 0.0049,  "MPa","APE1",    "4986"
14850   DATA 1, 6, 1, 1, 1, "S",  6.8792, 0.0562,  "MPa","APR2",    "5723"
14860   DATA 1, 7, 1, 1, 1, "S",  6.8636, 0.0708,  "MPa","APE2",    "5815"
14870   DATA 1, 8, 1, 1, 1, "S",  6.8643, 0.0806,  "MPa","APR3",    "5883"
14880   DATA 1, 9, 1, 1, 1, "S",  6.8531, 0.0562,  "MPa","APE3",    "5885"
14890   DATA 1,10, 1, 1, 1, "S",  13.709, 0.0757,  "MPa", "BP1",    "5887"
14900   DATA 1,11, 1, 1, 1, "S",  13.712, 0.1025,  "MPa", "BP2",    "5773"
14910   DATA 1,12, 1, 1, 1, "S",  13.734, 0.0806,  "MPa", "BP3",    "5892"
14920   DATA 1,13, 1, 1, 1, "S",  13.731, 0.0708,  "MPa", "BP4",    "5889"
14930   DATA 1,14, 1, 1, 1, "S",  13.717, 0.0635,  "MPa", "BP5",    "5891"
14940   DATA 1,15, 1, 1, 2, "S",     1.0,      0,  "  V","RAMP",   "      "
14950   DATA 1,16, 1, 1, 1, "S",  1000.0,      0,   "uE","BR1B",   "      "
14960 Card2:!
14970   DATA 2, 1 ,1, 1, 2, "S",  53.906, 1.3525,   "mm", "AD1",  "A22091"
14980   DATA 2, 2, 1, 1, 2, "S",  53.634, 1.3379,   "mm", "AD2",  "A33381"
14990   DATA 2, 3, 1, 1, 2, "S",  53.608, 1.4599,   "mm", "AD3",  "A33382"
15000   DATA 2, 4, 1, 1, 1, "S",  1000.0,      0,   "uE","BR1A",   "      "
15010   DATA 2, 5, 1, 1, 1, "S",  1000.0,      0,   "uE","BR2A",   "      "
```

```
15020   DATA 2, 6, 1, 1, 1, "S",  1000.0,        0,   "uE","FSG3",  "        "
15030   DATA 2, 7, 1, 1, 1, "S",  1000.0,        0,   "uE", "BS7",  "        "
15040   DATA 2, 8, 1, 1, 1, "S",  1000.0,        0,   "uE", "BS8",  "        "
15050   DATA 2, 9, 1, 1, 1, "S",  1000.0,        0,   "uE", "BS9",  "        "
15060   DATA 2,10, 1, 1, 1, "S",  1000.0,        0,   "uE", "BS1",  "        "
15070   DATA 2,11, 1, 1, 1, "S",  1000.0,        0,   "uE","BR2B",  "        "
15080   DATA 2,12, 1, 1, 1, "S",  1000.0,        0,   "uE", "BS3",  "        "
15090   DATA 2,13, 1, 1, 1, "S",  1000.0,        0,   "uE", "BS4",  "        "
15100   DATA 2,14, 1, 1, 1, "S",  1000.0,        0,   "uE", "BS2",  "        "
15110   DATA 2,15, 1, 1, 1, "S",  1000.0,   0.2881,   "uE","BR2C",  "        "
15120   DATA 2,16, 1, 1, 1, "S",  1000.0,        0,   "uE","BR1C",  "        "
15130    !-----|--|--|--|--|----|--------|--------|-------|------|---------|
15140    !Card |Ch|SW|HW|Ex|Mode|  Gain  | Offset | Units |  Ch  |  Serial |
15150    ! no. |no|gn|gn|gn|    |(Eng/V)|   (V)  | (/V)  |  Id  |  Number |
15160    !-----|--|--|--|--|----|--------|--------|-------|------|---------|
15170 End_transducers:!
15180    !
15190 Checks:!~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~!
15200    !   -- read transducer table                                          !
15210    !   -- check for extra transducers                                    !
15220    !   -- validate number of cards and channels                          !
15230    !   -- check for duplicate channels                                   !
15240    !   -- build data arrays                                              !
15250    !   -- validate gains                                                 !
15260    !   -- build data file array                                          !
15270    !-----------------------------------------------------------------!
15280    RESTORE Transducers                             !Read transducer table
15290    ON ERROR GOTO Err_no_data
15300    FOR Ch=1 TO No_channels
15310      READ Card_num(Ch),Card_channel(Ch),Sw_gain(Ch),Hw_gain(Ch),Ex_gain(Ch)
15320      READ Ch_mode$(Ch),Tx_gain(Ch),Tx_offset(Ch)
15330      READ Eng_units$(Ch),Ch_id$(Ch),Serial$(Ch)
15340    NEXT Ch
15350    ON ERROR GOTO Okay
15360    READ Card_num(No_channel+1)                     ! (Check for extra ch.)
15370    GOTO Err_more_data
15380 Okay:                                              !
15390    OFF ERROR
15400    IF ERRN<>36 THEN
15410      PRINT "Unexpected error while reading Transducer setup table."
15420      PRINT ERRM$
15430      BEEP
15440      PAUSE
15450    END IF
15460    !
15470    IF No_cards<>MAX(Card_num(*)) THEN Err_no_cards
15480    IF (No_channels MOD No_cards)<>0 THEN Err_n_cards
15490    !
15500    FOR I=1 TO No_channels                          !Check for duplicate ch.
15510      FOR J=1 TO No_channels
15520        IF I<>J THEN
15530          IF Ch_id$(I)=Ch_id$(J) THEN GOTO Err_dup_id
15540        END IF
15550      NEXT J
15560    NEXT I
15570    !
15580    REDIM Mode$(No_cards,No_channels/No_cards)      !Re-size data arrays
15590    REDIM Labels$(No_cards,No_channels/No_cards,SIZE(Labels$,3))
15600    REDIM Ad_gain(No_cards,No_channels/No_cards,SIZE(Ad_gain,3))
15610    REDIM Gains(No_cards,No_channels/No_cards,SIZE(Gains,3))
```

```
15620   !
15630   Ch=0
15640   FOR I=1 TO No_channels                              !Build data arrays from
15650     Cd=Card_num(I)                                    !transducer table
15660     Ch=Card_channel(I)
15670     IF Labels$(Cd,Ch,1)<>"$" THEN GOTO Err_dup_ch
15680     Labels$(Cd,Ch,1)=Ch_id$(I)
15690     Labels$(Cd,Ch,2)=Serial$(I)
15700     Labels$(Cd,Ch,3)=Eng_units$(I)
15710     Mode$(Cd,Ch)=Ch_mode$(I)
15720     Ad_gain(Cd,Ch,1)=Sw_gain(I)
15730     Ad_gain(Cd,Ch,2)=Hw_gain(I)
15740     Ad_gain(Cd,Ch,3)=Ex_gain(I)
15750     Gains(Cd,Ch,1)=(5*Ex_gain(I))/(2048*Sw_gain(I)*Hw_gain(I))
15760     Gains(Cd,Ch,2)=Tx_gain(I)
15770     Gains(Cd,Ch,3)=Tx_offset(I)
15780   NEXT I
15790   !
15800   Ch_count=0                                          !Check Ad-200 gains ok
15810   FOR Cd=1 TO SIZE(Gains,1)
15820     FOR Ch=1 TO SIZE(Gains,2)
15830       SELECT Ad_gain(Cd,Ch,1)
15840       CASE 0
15850         !(channel not implimented)
15860       CASE 1,2,5,10
15870         Ch_count1=Ch_count1+1
15880       CASE ELSE
15890         GOTO Err_invld_gain
15900       END SELECT
15910       !
15920       SELECT Ad_gain(Cd,Ch,2)
15930       CASE 0
15940         !(channel not implimented)
15950       CASE 1,4,10
15960         Ch_count2=Ch_count2+1
15970       CASE ELSE
15980         GOTO Err_invld_gain
15990       END SELECT
16000     NEXT Ch
16010   NEXT Cd
16020   IF Ch_count1<>No_channels THEN GOTO Err_no_channels
16030   IF Ch_count2<>No_channels THEN GOTO Err_no_channels
16040   !
16050   REDIM File_id$(No_cards,No_channels/No_cards,No_windows)
16060   !
16070   FOR Wdw=1 TO No_windows                             !Build file ID array
16080     FOR Ch=1 TO No_channels/No_cards
16090       FOR Cd=1 TO No_cards
16100         File_id$(Cd,Ch,Wdw)=Test_hdr$[1,5]&VAL$(Wdw)&Labels$(Cd,Ch,1)
16110       NEXT Cd
16120     NEXT Ch
16130   NEXT Wdw
16140   !
16150   DEALLOCATE Ch_id$(*),Ch_mode$(*),Eng_units$(*),Serial$(*)
16160   DEALLOCATE Card_channel(*),Card_num(*),Ex_gain(*)
16170   DEALLOCATE Hw_gain(*),Sw_gain(*),Tx_gain(*),Tx_offset(*)
16180   SUBEXIT
16190   !++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
16200 Err_no_cards:                                       !
16210   BEEP
```

```
16220   PRINT "Number of cards in error! (card(s) >  ";SIZE(Gains,1);")"
16230   PAUSE
16240   !
16250 Err_n_cards:                                   !
16260   BEEP
16270   PRINT "Number of channels not evenly divisible by number of cards!"
16280   PAUSE
16290   !
16300 Err_dup_id:                                    !
16310   BEEP
16320   PRINT "Duplicate label found: ";Ch_id$(I);" at ";I;" and ";J;"!"
16330   PAUSE
16340   !
16350 Err_dup_ch:                                    !
16360   BEEP
16370   PRINT "Duplicate channel found:";Labels$(Cd,Ch,1);" and ";Ch_id$(I);"!"
16380   PAUSE
16390   !
16400 Err_invld_gain:                                !
16410   BEEP
16420   PRINT "Invalid gain for channel ";Labels$(Cd,Ch,1);" =";Ad_gain(Cd,Ch,1)
16430   PAUSE
16440   !
16450 Err_no_channels:                               !
16460   BEEP
16470   PRINT "Sw_gain array does not add up to No_channels!"
16480   PAUSE
16490   !
16500 Err_no_data:                                   !
16510   BEEP
16520   IF ERRN=36 THEN
16530     PRINT "More channels than DATA statements in Transducer setup table!"
16540   ELSE
16550     PRINT ERRM$
16560   END IF
16570   PAUSE
16580   !
16590 Err_more_data:                                 !
16600   BEEP
16610   PRINT "More DATA statements than channels in Transducer setup table!"
16620   PAUSE
16630 SUBEND
16640 !_______________________________________________________________________
16650 Update_index:SUB Update_index
16660 !
16670 !This module enters the post-test status, etc. into the test index file.
16680 !========================================================================
16690   OPTION BASE 1
16700   COM /Files_1/ Index_file$,Test_hdr$[10],File_id$(*)
16710   COM /Files_2/ Msus$,Temp_files$(*),Hdr_size
16720   COM /Test_data/ Labels$(*),Gains(*),Test_time
16730   !---------------------------------------------------------------------
16740   INTEGER Test_status
16750   !
16760 Test_ok:                                       !Querry status
16770   DISP CHR$(129)
16780   INPUT " Was this test successful? (Y/N) ",Ans$
16790   DISP CHR$(128)
16800   SELECT UPC$(Ans$[1,1])
16810   CASE "Y"
```

```
16820      Test_status=0
16830    CASE "N"
16840      Test_status=1
16850    CASE ELSE
16860      GOTO Test_ok
16870    END SELECT
16880    !
16890    ASSIGN @File TO Index_file$&Msus$                  !Update index
16900    STATUS @File,7;Rec                                 ! (Set pointers to EOF)
16910    STATUS @File,8;Byt
16920    CONTROL @File,5;Rec
16930    CONTROL @File,6;Byt
16940    OUTPUT @File;Test_hdr$;Test_time;Test_status
16950    ASSIGN @File TO *
16960  SUBEND
16970  !_______________________________________________________________________
16980  Voltmeter:SUB Voltmeter(Window)
16990  !
17000  !This module monitors and displays the current voltage (or raw data) of
17010  !each active transducer.
17020  !
17030  !Inputs:
17040  !     Window    = acquisition iteration
17050  !Calls:
17060  !     Display
17070  !=======================================================================
17080    OPTION BASE 1
17090    COM /Ad_setup1/ INTEGER Card_no,Dvm_flag,No_cards,No_channels,Max_cards
17100    COM /Ad_setup2/ INTEGER Max_channels,No_windows,Trigger(*)
17110    COM /Ad_setup3/ Duration(*),No_samples(*),Period(*),Sample_rate(*)
17120    COM /Ad_setup4/ Ad_gain(*),Mode$(*),Preset$(*)
17130    COM /Files_1/ Index_file$(*),Test_hdr$(*),File_id$(*)
17140    COM /Infotek/ INTEGER Ad_addr(*),Code(*),Entry(*),Offset
17150    COM /Test_data/ Labels$(*),Gains(*),Test_time
17160    !-----------------------------------------------------------------------
17170    INTEGER Groups,Mode,Trig
17180    REAL Count,Time
17190    !
17200    Count=No_samples(1)                                !Save test parameters
17210    Time=Period(1)
17220    Trig=Trigger(1)
17230    !
17240    Dvm_flag=1                                         !Set DVM mode parameters
17250    Groups=1
17260    Display_mode=0
17270    No_samples(1)=1
17280    Period(1)=100000
17290    Trigger(1)=0
17300    !
17310    OUTPUT KBD;"K";
17320    PRINT TABXY(29,1);CHR$(129);" ***SYSTEM VOLTMETER*** ";CHR$(128)
17330    !
17340    ON KEY 1 LABEL "  STOP      DVM   " GOTO Kickstand
17350    ON KEY 2 LABEL " START      DVM   " GOTO Cycle
17360    ON KEY 3 LABEL "                  " GOSUB Not_used
17370    ON KEY 4 LABEL "DISPLAY  VOLTS    " GOSUB Volts
17380    ON KEY 5 LABEL "DISPLAY   RAW     " GOSUB Raw
17390    ON KEY 6 LABEL "DISPLAY   ENG     " GOSUB Eng
17400    ON KEY 7 LABEL "                  " GOSUB Not_used
17410    ON KEY 8 LABEL "  EXIT     DVM    " GOTO Quit
```

```
17420   !
17430 Cycle:                                          !Update DVM
17440   LOOP
17450     WAIT .1
17460     GOSUB Read
17470   END LOOP
17480   !
17490 Kickstand:                                      !Freeze DVM
17500   DISP "DVM idle........."
17510   ON ERROR GOTO Spin
17520   DEALLOCATE Voltmeter(*)
17530   OFF ERROR
17540 Spin:                                           !Zzzzz...........
17550   GOTO Spin
17560   !
17570 Quit:                                           !Abort DVM
17580   Dvm_flag=0                                    !Restore test parameters
17590   No_samples(1)=Count
17600   Period(1)=Time
17610   Trigger(1)=Trig
17620   !
17630   OUTPUT KBD;"K";                              !Exit
17640   LOAD KEY "KEYS"
17650   SUBEXIT
17660   !++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
17670 Read:                                           !Acquire voltmeter data
17680   ALLOCATE INTEGER Voltmeter(Groups,No_samples(1),No_channels/No_cards,No_
17690   SELECT No_cards
17700   CASE 1                                        !From One Ad-200 card
17710     ASSIGN @Voltmeter TO BUFFER [No_channels*No_samples(1)*2]
17720     Das_1_ad200(@Voltmeter,Window)
17730     ENTER @Voltmeter USING "#,W";Voltmeter(*)
17740     ASSIGN @Voltmeter TO *
17750   CASE 2 TO 4                                   !From 2/4 Ad-200 cards
17760     Das_4_ad200(1,Voltmeter(*))
17770   END SELECT
17780   Display(Display_mode,Voltmeter(*))
17790   DEALLOCATE Voltmeter(*)
17800   RETURN
17810   !
17820 Volts:                                          !Display mode volts
17830   Display_mode=0
17840   RETURN
17850   !
17860 Raw:                                            !Display mode raw
17870   Display_mode=1
17880   RETURN
17890   !
17900 Eng:                                            !Display mode eng
17910   Display_mode=2
17920   RETURN
17930   !
17940 Not_used:                                       !Unused key
17950   RETURN
17960 SUBEND
17970 !__________________________________________________________________________
17980 Write_header:SUB Write_header
17990 !
18000 !This module creates and writes into the test header file.
18010 !==========================================================================
18020   OPTION BASE 1
18030   COM /Ad_setup1/ INTEGER Card_no,Dvm_flag,No_cards,No_channels,Max_cards
18040   COM /Ad_setup2/ INTEGER Max_channels,No_windows,Trigger(*)
18050   COM /Ad_setup3/ Duration(*),No_samples(*),Period(*),Sample_rate(*)
18060   COM /Ad_setup4/ Ad_gain(*),Mode$(*),Preset$(*)
18070   COM /Files_1/ Index_file$,Test_hdr$[10],File_id$(*)
18080   COM /Files_2/ Msus$,Temp_files$(*),Hdr_size
18090   COM /Test_data/ Labels$(*),Gains(*),Test_time
18100   !------------------------------------------------------------------
18110   ALLOCATE Rate(No_windows)
18120   !
18130   ON ERROR GOSUB Purge_index                        !Build test header file
18140   CREATE BDAT Test_hdr$&Msus$,Hdr_size
18150   OFF ERROR
18160   !
18170   FOR Wdw=1 TO No_windows                           !Calc. S.R. / ch. / window
18180     Rate(Wdw)=Sample_rate(Wdw) DIV (No_channels/No_cards)
18190   NEXT Wdw
18200   !
18210   ASSIGN @Index TO Test_hdr$&Msus$                  !Download test parameters
18220   OUTPUT @Index;No_windows
18230   OUTPUT @Index;No_cards
18240   OUTPUT @Index;No_channels
18250   OUTPUT @Index;Max_cards
18260   OUTPUT @Index;Max_channels
18270   OUTPUT @Index;Duration(*)
18280   OUTPUT @Index;Rate(*)
18290   OUTPUT @Index;Labels$(*)
18300   OUTPUT @Index;Mode$(*)
18310   OUTPUT @Index;Ad_gain(*)
18320   OUTPUT @Index;Gains(*)
18330   ASSIGN @Index TO *
18340   !
18350   DEALLOCATE Rate(*)
18360   SUBEXIT
18370   !++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
18380 Purge_index:  !
18390   OFF ERROR
18400   IF ERRN<>54 THEN
18410     PRINT ERRM$
18420     PAUSE
18430   ELSE
18440     PURGE Test_hdr$&Msus$
18450   END IF
18460   RETURN
18470 SUBEND
18480 !____________________________________________________________________
18490 Ad200_check:SUB Ad200_check(@Path,Card,String1$)
18500 !
18510 !This module reads the status register in the AD-200 card, and, if it
18520 !contains errors, prints an error list and stops the programme.
18530 !--------------------------------------------------------------------
18540   OPTION BASE 1
18550   ALLOCATE Status$[10]
18560   !
18570   OUTPUT @Path;"STATUS"
18580   ENTER @Path;Status$
18590   !
18600   IF Status$<>"--------" THEN
18610     DISP CHR$(129)
```

```
18620     DISP " Status error ";String1$;Card
18630     BEEP
18640     PRINT RPT$("_",28);" Command Error List ";RPT$("_",28)
18650     IF Status$[1,1]<>"-" AND Status$[4,4]<>"-" THEN
18660       PRINT "Unused status point error...???"
18670     END IF
18680     IF Status$[2,2]="p" THEN
18690       PRINT "Illegal PERIOD ... "
18700     END IF
18710     IF Status$[3,3]="u" THEN
18720       PRINT "Unrecognized command ..."
18730     END IF
18740     IF Status$[5,5]="s" THEN
18750       PRINT "SELECT error ... "
18760     END IF
18770     IF Status$[6,6]="c" THEN
18780       PRINT "COUNT error ... "
18790     END IF
18800     IF Status$[7,7]="t" THEN
18810       PRINT "TIME error ... "
18820     END IF
18830     IF Status$[8,8]="o" THEN
18840       PRINT "Buffer over-run ... "
18850     END IF
18860     PRINT RPT$("_",76)
18870     PAUSE
18880   END IF
18890   !
18900   DEALLOCATE Status$
18910   DISP CHR$(128)
18920 SUBEND
18930 !___________________________________________________________________________
18940 Start_test:SUB Start_test(Test_time,INTEGER Dvm_flag)
18950 !
18960 !===========================================================================
18970   OPTION BASE 1
18980   !
18990   SELECT Dvm_flag
19000   CASE 0
19010 Start_tst:                                             !Start test
19020     Ans$=" "
19030     DISP CHR$(129)
19040     INPUT " START TEST? (Y/N) ",Ans$
19050     DISP CHR$(128)
19060     SELECT UPC$(Ans$[1])
19070     CASE "N"
19080       Ans$=" "
19090       DISP CHR$(129)
19100       INPUT " Abort this test? (Y/N) ",Ans$
19110       IF UPC$(Ans$[1])="Y" THEN
19120         DISP " TTFN "
19130         DISP CHR$(128)
19140         STOP
19150       END IF
19160     CASE "Y"
19170       Test_time=TIMEDATE
19180     CASE ELSE
19190       GOTO Start_tst
19200     END SELECT
19210   CASE 1                                                !Voltmeter
```

```
19220      ! (DVM Express. Let'r rip!)
19230    END SELECT
19240 SUBEND
19250 !______________________________________________________________________
19260 Setup_test:SUB Setup_test
19270 !
19280 !======================================================================
19290    OPTION BASE 1
19300    COM /Ad_setup1/ INTEGER Card_no,Dvm_flag,No_cards,No_channels,Max_cards
19310    COM /Ad_setup2/ INTEGER Max_channels,No_windows,Trigger(*)
19320    COM /Ad_setup3/ Duration(*),No_samples(*),Period(*),Sample_rate(*)
19330    COM /Ad_setup4/ Ad_gain(*),Mode$(*),Preset$(*)
19340    COM /Files_1/ Index_file$,Test_hdr$[10],File_id$(*)
19350    COM /Files_2/ Msus$,Temp_files$(*),Hdr_size
19360    COM /Test_data/ Labels$(*),Gains(*),Test_time
19370    !--------------------------------------------------------------------
19380    !
19390 Enter_variables:                                  !Enter test parameters
19400    REDIM Sample_rate(No_windows),Duration(No_windows)
19410    DISP CHR$(129)
19420    FOR Wdw=1 TO No_windows
19430      REPEAT
19440        SELECT No_cards
19450        CASE 1
19460          INPUT " Enter aggregate SAMPLE RATE. (.5 <= Hz <= 100,000) ",Sampl
19470        CASE 2 TO 4
19480          INPUT " Enter aggregate SAMPLE RATE. (.5 <= Hz <= 70,000) ",Sample
19490        END SELECT
19500        INPUT " Enter TEST DURATION. (Seconds) ",Duration(Wdw)
19510        IF Sample_rate(Wdw)=0 OR Duration(Wdw)=0 THEN BEEP
19520      UNTIL Sample_rate(Wdw)<>0 AND Duration(Wdw)<>0
19530    NEXT Wdw
19540    DISP CHR$(128)
19550    !
19560 Ad200_calc:                                       !TIME, COUNT calculations
19570    FOR Wdw=1 TO No_windows                        !Calc sample PERIOD
19580      Period(Wdw)=INT(1.E+9/(Sample_rate(Wdw)))
19590      WHILE Period(Wdw) MOD 50<>0
19600        Period(Wdw)=Period(Wdw)-1
19610      END WHILE
19620      !
19630      SELECT No_cards                              !PERIOD within limits?
19640      CASE 1
19650        IF Period(Wdw)<1.0E+4 OR Period(Wdw)>5.0E+8 THEN
19660          PRINT "Eek!! Ad-200 period";Wdw;"out of range in Setup_test! Perio
19670          BEEP
19680          GOTO Enter_variables
19690        END IF
19700      CASE 2 TO 4
19710        IF Period(Wdw)<1.43+4 OR Period(Wdw)>5.E+8 THEN
19720          PRINT "Eek!! Ad-200 period";Wdw;"out of range in Setup_test! Perio
19730          BEEP
19740          GOTO Enter_variables
19750        END IF
19760      END SELECT
19770      !
19780      Sample_rate(Wdw)=1.0E+9 DIV (Period(Wdw))
19790      !
19800      No_samples(Wdw)=(Duration(Wdw)/(Period(Wdw)*1.0E-9))
19810      IF FRACT(No_samples(Wdw))<>0 THEN
```

```
19820       No_samples(Wdw)=INT(No_samples(Wdw))+1
19830     END IF
19840     WHILE No_samples(Wdw) MOD No_channels<>0
19850       No_samples(Wdw)=No_samples(Wdw)+1
19860     END WHILE
19870     !
19880     IF No_samples(Wdw)<1 OR No_samples(Wdw)>1.E+7 THEN
19890       DISP "Eek!  Ad-200 No_samples(";Wdw;") out of bounds in ""Setup_test
19900       PAUSE
19910     END IF
19920   NEXT Wdw
19930 SUBEND
19940 !_____________________________________________________________________
19950 Arb_init:SUB Arb_init(Window)
19960 !
19970 !This module initializes the Wavetek 175 Arbitrary Waveform Generator for
19980 !one window only.
19990 !
20000 !Inputs:
20010 !    Window = acquisition reiteration (good for one only)
20020 !======================================================================
20030   OPTION BASE 1
20040   COM /Ad_setup3/ Duration(*),No_samples(*),Period(*),Sample_rate(*)
20050   COM /Arb_gen/ Arb_addr
20060   !---------------------------------------------------------------------
20070   ALLOCATE Arb_stg1$[80],Arb_stg2$[80],T$[10]
20080   REAL A,Pwr
20090   !
20100   A=0                                      !Select variables
20110   B=1
20120   C=3
20130   DISP CHR$(129)
20140   REPEAT
20150     INPUT " Select max amplitude: (0< A <=5) ",A
20160     INPUT " Select trigger mode: (INT = 0, EXT = 1 (default)) ",B
20170     INPUT " Select waveform: 0=sin, 1=tri, 2=sqr, 3=rmp (default) ",C
20180     IF A<=0 OR A>10 OR B<0 OR B>1 OR C<0 OR C>3 THEN BEEP
20190   UNTIL A>0 AND A<=5 AND B>=0 AND B<=1 AND C>=0 AND C<=3
20200   DISP CHR$(128)
20210   !
20220   A=A/2                                    !Calc actual amp, offset
20230   D=A/2                                    !(Offset + ARB o/p offset)
20240   !
20250   Cmd_dur=Duration(Window)
20260   PRINT TABXY(1,19);"Default command duration =";Duration(Window);" sec."
20270   Ans$="n"
20280   DISP CHR$(129)
20290   INPUT " Select new command duration? (Default = no)",Ans$
20300   IF UPC$(Ans$[1])="Y" THEN
20310     INPUT " Enter new command duration. (Seconds) ",Cmd_dur
20320     PRINT TABXY(1,19);RPT$(" ",80)
20330     PRINT TABXY(1,19);"New command duration =";Cmd_dur;" sec."
20340   END IF
20350   DISP CHR$(128)
20360   T=Cmd_dur/256                            !Calc Arb sample time
20370   Pwr=0
20380   WHILE T<1 AND Pwr>-9
20390     T=T*10
20400     Pwr=Pwr-1
20410   END WHILE
```

```
20420   T$=VAL$(PROUND(T,-3))&"E"&VAL$(Pwr)
20430   PRINT RPT$(" ",80)
20440   !
20450   Arb_stg1$="A"&VAL$(A)&" B"&VAL$(B)&" C"&VAL$(C)&" D"&VAL$(D)&" L1 M0"
20460   Arb_stg2$=" N0 P1 Q1 O1 R0 T"&T$&" U0 V0 W255 I"
20470   !
20480   ASSIGN @Arb TO Arb_addr                            !Initialize ARB GEN
20490   OUTPUT @Arb;"Z"
20500   WAIT 1
20510   OUTPUT @Arb;Arb_stg1$;Arb_stg2$
20520   !
20530   Status=SPOLL(@Arb)                                 !Check for SRQ (errors)
20540   IF Status<>32 THEN
20550     PRINT "ARB GEN setup error!!! Programme paused in Arb_init."
20560     PAUSE
20570   END IF
20580   LOCAL @Arb
20590   ASSIGN @Arb TO *
20600   !
20610   DEALLOCATE Arb_stg1$,Arb_stg2$,T$
20620 SUBEND
20630 !_____________________________________________________________________________
20640 Mem_needed:DEF FNMem_needed
20650 !
20660 ! Determines the amount of memory space required, in words.
20670 !=============================================================================
20680   OPTION BASE 1
20690   COM /Ad_setup1/ INTEGER Card_no,Dvm_flag,No_cards,No_channels,Max_cards
20700   COM /Ad_setup2/ INTEGER Max_channels,No_windows,Trigger(2)
20710   COM /Ad_setup3/ Duration(2),No_samples(2),Period(2),Sample_rate(2)
20720   !---------------------------------------------------------------------------
20730   Words=0                                            !Check memory space
20740   FOR Window=1 TO No_windows
20750     Words=Words+Sample_rate(Window)*Duration(Window)*No_cards
20760   NEXT Window
20770   RETURN Words+5.E+4
20780 FNEND
20790 !_____________________________________________________________________________
20800 Mem_space:DEF FNMem_space
20810 !
20820 ! Determines the amount of memory space available, in words.
20830 !=============================================================================
20840   RETURN VAL(SYSTEM$("AVAILABLE MEMORY")) DIV 2
20850 FNEND
20860 !_____________________________________________________________________________
20870 !*****************************************************************************
```

```
2 !RE-STORE "PROP PLOT: 700 0"
4    !   ***********************************************************************
6    ! |                                                                     |
8    ! |                                                                     |
10   ! |Calling name: PROP PLOT                          Version: 2.0        |
12   ! |Programmer   : N Chalk                           Date    : 18 Feb 1988 |
14   ! |---------------------------------------------------------------------|
16   ! |Description:                                                         |
18   ! | - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - |
20   ! |Root programmes: PERDPLOT /  5 Mar 1987                              |
22   ! |                 KIGPLOT  / 23 Mar 1986                              |
24   ! |_____________________________________________________________________|
26   ! |Modifcation history                                  |Date      |By      |
28   ! |-----------------------------------------------------|----------|--------|
30   ! | 1. Install Actuator Load and Total Load calculation |30 Apr 88| NC      |
32   ! |    module "Act_load".                               |          |        |
34   ! | 2. Install Principal Strain calculation module.     |13 May 88| NC      |
36   ! |    "Principal_e".                                   |          |        |
38   ! | 3. Fixed routine 'No_file_found' in module          |16 May 88| NC      |
40   ! |    "Raw_to_int" so it will prompt for another floppy|          |        |
42   ! |    if the MSU is a floppy drive unit.               |          |        |
44   ! | 4.                                                  |          |        |
46   ! | 5.                                                  |          |        |
48   !   ***********************************************************************
50     OPTION BASE 1
52     COM /Index_string/ Buff_id$(150,2)[10],Buff_title$(150,2)[40],Buff_units$(
54     COM /Index_real/ Buff_freq(150,2),Buff_gain(150,2),Buff_offset(150,2),Buff
56     COM /Index_points/ REAL No_buffers(2),Buff_points(150,2),Buff_start(150,2)
58     COM /Raw_defaults/ INTEGER No_avg,Skip,REAL Start_time,Stop_time
60     COM /Index_defaults/ Sample_freq,Events(3)
62     COM /Buff_defaults/ Buff_ingain
64     COM /Msus/ Msus_raw1$[15],Msus_raw2$[15],Msus_buff$[15],Msus_ext$[15],Test
66 Acc_sizer:COM /Accumulators/ No_acc,Acc_size,Acc1(6000),Acc2(6000),Acc3(6000)
68     COM /Graph_limits/ Viewxmin,Viewxmax,Viewymin,Viewymax,Xmin,Xmax,Ymin,Ymax
70     COM /Graph_stuff/ Color(6),Line(6),Overlay_no,Full_screen,Split_format,Aut
72     COM /Calc_modules/ Module_index$(150,3)[30],First_calc,No_calcs
74     COM /Transducers/ Labels$(2,16,3)[10],Mode$(2,16)[1],Ad_gain(2,16,3),Gains
76     COM /Hardware/ Prt_address,Current_prt,Computer$[10]
78     COM /Autosequence/ INTEGER Seq_no,Seq_flag,Sequence$(120)[30]
80     COM /Responses/ Response_id$[20],Ch_id$[20]
82     !-------------------------------------------------------------------------
84     MAT Buff_gain= (0)
86     Clear_screen
88     !
90     Acc_size=SIZE(Acc1,1)
92     No_acc=6
94 Accumulators:                                                  !
96     ! If changing accumulator size, also change size of buffers
98     !  located at line "Raw_buff_size" .
100    ! CHANGE "(5000)" TO "(6000)" IN Acc_sizer,Acc_sizer:ALL
102    ! CHANGE "(5000)" TO "(6000)" IN Raw_buff_size,Raw_buff_size:ALL
104    !
106 Sequence:                                                      !Auto calc sequence
108    DATA JUNK
110    DATA END
112    !
114    RESTORE Sequence
116    I=0
118    REPEAT
120      I=I+1
```

```
122      READ Sequence$(I)
124    UNTIL UPC$(Sequence$(I))="END" OR I=SIZE(Sequence$,1)
126    REDIM Sequence$(I-1)
128    Seq_no=0
130    !
132  Disk_stuff:                                         !Disk stuff
134    Msus_raw1$=":,700,0"
136    Msus_buff$=":,0,3"
138    Msus_ext$=":,700,1"
140    Msus_raw2$=Msus_buff$
142    !-----------------------!
144    ! Initialize a RAMdisk   !
146    !-----------------------!----------------------------!
148    INITIALIZE ":,0,3",5      ! Turf old ramdisk            !
150                              !----------------------------!
152    Mem_left=VAL(SYSTEM$("AVAILABLE MEMORY"))
154    Disk_bytes=MIN(2.5E+5,Mem_left-3*8*Acc_size)
156    IF Disk_bytes<0 THEN
158      Clear_screen
160      BEEP
162      PRINT "Not enough available memory for RAMdisk buffers."
164      PRINT "Contact GEOTECH Software Support Services for further information
166      STOP
168    END IF
170    PRINT "Initializing a RAMdisk of ";Disk_bytes;" bytes for the buffer files
172    INITIALIZE ":MEMORY,0,3",INT(.5+Disk_bytes/256)
174    !----------------------------!
176    !  GRAPHICS                   !
178    !----------------------------!
180  Graph_stuff:!
182    Split_format=0                ! 0 - top and bottom splitscreen plots
184                                  ! 1 - side by side splitscreen plots
186    !-----------------------------!
188    Auto_dump=-1                  !  1 - automatically dump plots to printer
190                                  ! -1 - replots everything using plotter
192                                  !  0 - waits for user to press ENTER
194                                  ! (else) - no waits between plots
196    !-----------------------------!
198    Auto_scale=1                  ! 1 - Automatic scaling with user override
200                                  ! 0 - No automatic scaling.
202                                  ! -1  Full automatic, no override.
204    !-----------------------------!
206    Page_header=1                 ! 0 - Plot_set does not call Plot_titles
208                                  ! 1 - Does call Plot_titles
210    !-----------------------------!
212  Plot_colors:DATA 1,2,3,4        !
214    !-----------------------------!
216  Plot_lines:DATA 1,4,6,8         !
218    !-----------------------------!
220    No_pens=4                     !
222    !-----------------------------!
224    REDIM Color(No_pens),Line(No_pens)
226    RESTORE Plot_colors
228    READ Color(*)
230    RESTORE Plot_lines
232    READ Line(*)
234    !-----------------------------!
236                                  !
238    PLOTTER IS CRT,"INTERNAL"
240    IF TRIM$(SYSTEM$("SYSTEM ID"))="9816" THEN
```

```
242     DISP "9816 MODE..."
244     REDIM Screen(400,19)
246   END IF
248   CONTROL 1,12;2
250   !
252   !-------------------------------------!
254   !   OTHER DEFAULTS                    !
256   !-------------------------------------!
258 Defaults:  !
260   Seq_flag=0
262   First_calc=0
264   Full_screen=0
266   Prt_address=701
268   Current_prt=CRT
270   Computer$=TRIM$(SYSTEM$("SYSTEM ID")) !  Possible contents of Computer$:
272   !                                     !        "9816"   &   "5300:10"
274   !----------------------------!
276   Buff_ingain=0                !  1- Buffers are REAL
278   !----------------------------!  0- Buffers are INTEGER
280   No_avg=0
282   Skip=0
284   Start_time=0
286   Stop_time=20
288   !
290   !-------------------------------------!
292   !    INITIALIZE, START                !
294   !-------------------------------------!
296 Start:                                                 !
298   MAT Screen= (0)                                      ! (Clear graphics CRT mem)
300   Clear_screen
302   Clear_index(1)
304   Clear_index(2)
306   Create_index                                         ! (Loads hdr->req'sts ram)
308   !
310 Begin:                                                 !
312   Menus
314   !
316 End_of_program:                                        !
318   Clear_screen
320   INPUT "Are you sure you want to exit now?",Ans$
322   Ans$=UPC$(Ans$)
324   IF Ans$<>"Y" THEN GOTO Begin
326   IF Computer$<>"9816" THEN
328     CONTROL 2,15;0
330   END IF
332   Clear_index(1)
334   Clear_index(2)
336   END
338   !*****************************************************************!
340   !*****************************************************************!
342 Acc_int_1t:SUB Acc_int_1t(Delta_t)
344   !
346   ! Integrate contents of accumulator 1 over time.
348   ! Place integrated output in accumulator 2.
350   !   Delta_t is time increment between samples
352   !===================================================================
354     OPTION BASE 1
356     COM /Accumulators/ No_acc,Size_acc,Acc1(*),Acc2(*),Acc3(*),Acc4(*),Acc5(
358     !-----------------------------------------------------------------
360     DISP "Integrating.."
```

```
362      !----------------------------!
364      ! Initial value for Integration = 0
366      !----------------------------!
368      Int=0
370      REDIM Acc2(SIZE(Acc1,1))
372      Acc2(1)=Int
374      FOR I=3 TO -1+SIZE(Acc1,1) STEP 2
376        Int=Int+2*Acc1(I)+4*Acc1(I+1)
378        Acc2(I)=Int*Delta_t/3
380        Acc2(I-1)=.5*(Acc2(I)+Acc2(I-2))
382      NEXT I
384      !
386      DISP
388    SUBEND
390    !____________________________________________________________________________
392 Acc_to_buff:SUB Acc_to_buff(Acc_no,Id$,Title$,Units$,Ingain,Inoffset)
394    !
396    ! Transfer contents of selected accumulator into disk data buffer.
398    ! User is queried if new buffer id$ is same as existing one.
400    ! Sample frequency,events and start time are assumed to be default.
402    ! See SUB Temp_to_buff for other input parameter descriptions.
404    !============================================================================
406      OPTION BASE 1
408      COM /Index_defaults/ Sample_freq,Events(*)
410      COM /Raw_defaults/ INTEGER No_avg,Skip,REAL Start_time,Stop_time
412      !---------------------------------------------------------------------------
414      ALLOCATE Buffdata(FNSize_acc)
416      !
418      Acc_to_temp(Acc_no,Buffdata(*))
420      Temp_to_buff(Buffdata(*),Id$,Title$,Units$,Sample_freq,0,Events(*),Ingai
422      DEALLOCATE Buffdata(*)
424    SUBEND
426    !____________________________________________________________________________
428 Acc_to_temp:SUB Acc_to_temp(Acc_no,Outdata(*))
430    !
432    ! This gets data from one of the accumulators and
434    ! puts it into the output data array.
436    !============================================================================
438      OPTION BASE 1
440      COM /Accumulators/ No_acc,Size_acc,Acc1(*),Acc2(*),Acc3(*),Acc4(*),Acc5(
442      !---------------------------------------------------------------------------
444      SELECT Acc_no
446      CASE >No_acc
448        PRINT "Selected accumulator number not available:";Acc_no
450        BEEP
452        SUBEXIT
454      CASE 1
456        MAT Outdata= Acc1
458      CASE 2
460        MAT Outdata= Acc2
462      CASE 3
464        MAT Outdata= Acc3
466      CASE 4
468        MAT Outdata= Acc4
470      CASE 5
472        MAT Outdata= Acc5
474      CASE 6
476        MAT Outdata= Acc6
478      CASE ELSE
480        DISP "Accumulator number  invalid:";Acc_no
```

```
482    BEEP
484    PRINT "in Acc_to_temp"
486    SUBEXIT
488   END SELECT
490  SUBEND
492  !_____________________________________________________________________
494  !
496 Ad_summary:SUB Ad_summary
498  !
500  ! Lists info about the acquisition on the current printer.
502  ! This includes gain and offset factors.
504  !=====================================================================
506   OPTION BASE 1
508   COM /Transducers/ Labels$(*),Mode$(*),Ad_gains(*),Gains(*)
510   COM /Hardware/ Prt_address,Current_prt,Computer$
512   !--------------------------------------------------------------------
514   Clear_screen
516   Un$=CHR$(132)
518   Nor$=CHR$(128)
520   PRINT " ";Un$;"  A/D summary                               ";Nor$;"  ";Un$;"
522   PRINT "|TXDCR | Eng. |  A/D  | TXDCR | TXDCR||TXDCR | Eng. |  A/D  | TXD
524   PRINT "|";Un$;"  ID  |Units | gain  | gain  |offset";Nor$;"||";Un$;"  ID
526   Lines=3
528   FOR I=1 TO 4
530    FOR J=1 TO 16 STEP 2
532     IF Labels$(I,J,1)="" THEN GOTO Over_there_too
534     PRINT USING Ad_image;"|";Labels$(I,J,1);"|";Labels$(I,J,3);"|";Gains
536     PRINT USING Ad_image;"|";Labels$(I,J+1,1);"|";Labels$(I,J+1,3);"|";G
538     Lines=Lines+1
540     PRINT
542     IF J=16 THEN
544      IF Lines<18 THEN
546       GOTO Over_there
548      ELSE
550       Lines=0
552       PRINT CHR$(129);" Press Return ";CHR$(128)
554       Wait_for_key
556      END IF
558     END IF
560     IF Lines=18 AND Labels$(I,J+1,1)<>"" AND Current_prt=CRT THEN
562      Lines=0
564      PRINT CHR$(129);" Press Return ";CHR$(128)
566      Wait_for_key
568     END IF
570 Over_there:  !
572    NEXT J
574   NEXT I
576 Over_there_too:  !
578 Ad_image:IMAGE $,1A,6A,1A,6A,1A,2X,DDD.D,1A,2X,DDD.D,1A,1X,DDD.D,1A
580   PRINT "|";Un$;"      |      |       |       |       ";Nor$;"||";Un$;"
582  SUBEND
584  !_____________________________________________________________________
586  !
588 Ask_for_channel:SUB Ask_for_channel(Type,Prompt$,Channel$,INTEGER Flag,REAL
590  !
592  ! Prompts the user to enter a data channel or calculation module Id$.
594  ! If "?" or "/" is entered instead, the available channels are listed.
596  ! Exec_modules is called to check whether the selected channel or module
598  ! is valid - if a calc module is chosen, it is executed.
600  !
```

```
602  ! INPUTS:                   Type - defines what type of channels are wanted:
604  !                                  -1    any (Raw, Buff, Calc modules)
606  !                                   0    Calc modules only
608  !                                   1    Raw data files only
610  !                                   2    Buffer data files only
612  !=====================================================================
614     OPTION BASE 1
616 Query:                                                   !
618     PRINT
620     PRINT TABXY(0,19);RPT$(" ",80)
622     PRINT TABXY(0,19);Prompt$
624     Channel$=" "
626     INPUT Channel$
628     Channel$=TRIM$(UPC$(Channel$))
630     !
632     IF Channel$="?" OR Channel$="/" THEN
634       Clear_screen
636       SELECT Type
638       CASE -1
640         Print_index(1)
642         Print_index(2)
644         List_calcs
646       CASE 0
648         List_calcs
650       CASE 1
652         Print_index(1)
654       CASE 2
656         Print_index(2)
658       END SELECT
660       PRINT
662       GOTO Query
664     END IF
666     Exec_module(Channel$,Flag,Row)
668     !
670     OUTPUT KBD;"T";
672     PRINT TABXY(0,19);RPT$(" ",80)
674   SUBEND
676   !______________________________________________________________________
678 Auto_scale:SUB Auto_scale(Xmin,Xmax,Ymin,Ymax,Auto,Xtick,Ytick,Xmajor,Ymajor
680   !
682   !  Auto_scale                      Last mod: 02/08/86
684   !
686   !  Purpose: to check for 0 values of Ymax and Xmax
688   !           to separate into a separate subprogram
690   !
692   !  This subprogram modifies the max and min limits before plotting
694   !  given the limits of the data.  It also sets the tick marks, etc.
696   !  for the Plot_label subprogram.
698   !  It is called from the Plot_label subprogram.
700   !  VARIABLES:
702   !         Xmin->Ymax          Limits of the data, rounded in program.
704   !         Xtick               Number of ticks on the x axis
706   !         Ytick               Number of ticks on the y axis
708   !         Xmajor,Ymajor       Number of minor ticks per major tick
710   !         Xnos,Ynos           Number of values printed on each axis
712   !=====================================================================
714     OPTION BASE 1
716     COM /Raw_defaults/ INTEGER No_avg,Skip,REAL Start_time,Stop_time
718     COM /Hardware/ Prt_address,Current_prt,Computer$
720     COM /Autosequence/ INTEGER Seq_no,Seq_flag,Sequence$(*)
```

```
722       DIM Tick_array(20),Major_array(20),Value_array(20)
724       !-------------------------------------------------------------------------
726       INTEGER Range_calc
728       !*
730       !* This puts the values of tick marks, major ticks, values into arrays.
732       !*
734       RESTORE
736       !     1   2   3  4  5   6  7  8  9  10 11 12 13 14 15 16 17 18 19  20
738       DATA 100,100,60,80,100,60,70,80,90,100,55,60,65,70,75,80,85,90,95,100
740       DATA  10, 25,10,10, 10,10,10,10,10, 10, 5,10, 5,10,15,10,10,20,10, 20
742       DATA   5,  4, 6, 4, 5 , 6, 7, 4, 9,  5,11, 6,13, 7, 5, 8,17, 9, 9,  5
744       !
746       READ Tick_array(*)
748       READ Major_array(*)
750       READ Value_array(*)
752       !
754       ! This adjusts the values of Ymin and Ymax
756       !
758 Set_y_scales:                                              !Check for 0 value
760       IF Ymax<>0 THEN                                      !Find max values
762         Maxpower=INT(LGT(ABS(Ymax)))
764         Maxmantissa=10^FRACT(LGT(ABS(Ymax)))
766         IF Ymax<0 THEN
768           Maxmantissa=-1*Maxmantissa
770         END IF
772       ELSE
774         Maxpower=1
776         Maxmantissa=0
778       END IF
780       IF Ymin<>0 THEN                                      !Find min values
782         Minpower=INT(LGT(ABS(Ymin)))
784         Minmantissa=10^FRACT(LGT(ABS(Ymin)))
786         IF Ymin<0 THEN
788           Minmantissa=-1*Minmantissa
790         END IF
792       ELSE
794         Minpower=1
796         Minmantissa=0
798       END IF
800       Signsum=SGN(Ymax)+SGN(Ymin)                         !SELECT the sum of the
802       SELECT Signsum                                       !signs of Ymax and Ymin
804       CASE 2,1                                             ! CASE both positive, or
806         Minmantissa=0                                      ! one positive, one zero
808         I=0
810         LOOP
812           I=I+1
814           IF Maxmantissa<I THEN
816             Maxmantissa=I
818           END IF
820         EXIT IF Maxmantissa=I
822         END LOOP
824       CASE -2,-1                                           ! CASE both negative, or
826         Maxmantissa=0                                      ! one negative, one zero
828         I=0
830         LOOP
832           I=I-1
834           IF Minmantissa>I THEN
836             Minmantissa=I
838           END IF
840         EXIT IF Minmantissa=I
```

```
842          END LOOP
844        CASE 0                                           ! CASE one negative and
846          I=0                                            ! one positive
848          LOOP
850            I=I+1
852            IF Maxmantissa<I THEN
854              Maxmantissa=I
856            END IF
858          EXIT IF Maxmantissa=I
860          END LOOP
862          I=0
864          LOOP
866            I=I-1
868            IF Minmantissa>I THEN
870              Minmantissa=I
872            END IF
874          EXIT IF Minmantissa=I
876          END LOOP
878          IF Maxpower>Minpower THEN
880            Minmantissa=-1.0
882            Minpower=Maxpower
884          END IF
886          IF Minpower>Maxpower THEN
888            Maxmantissa=1.0
890            Maxpower=Minpower
892          END IF
894        CASE ELSE
896          PRINT "SIGNSUM INCORRECT"
898          PAUSE                                          !Oops
900        END SELECT
902        Ymax=Maxmantissa*10^Maxpower
904        Ymin=Minmantissa*10^Minpower
906        GOSUB Y_limits
908        !
910        ! If automatic sequence is being executed,
912        ! use predefined time window to set X-axis.
914        !
916        IF Seq_flag=1 THEN
918          GOTO Set_to_window
920        ELSE
922          GOTO Set_x_scales
924        END IF
926        !
928        ! Set Ytick, Ymajor, Yvalues (Subroutine)
930        !
932        Range_calc=0
934 Y_limits:                                              !
936        IF Range_calc=0 THEN
938          Yrange=10^FRACT(LGT(ABS(Ymax-Ymin)))
940        END IF
942        IF Yrange<>0 THEN
944   !      IF Auto<>-1 THEN PRINT TABXY(64,1);"Range=";Yrange
946          Ytick=Tick_array(Yrange)
948          Ymajor=Major_array(Yrange)
950          Yvalues=Value_array(Yrange)
952        ELSE
954          PRINT "RANGE=0:  error in Auto_scale subprogram (Set_y_scales)"
956          PAUSE
958        END IF
960        RETURN
```

```
962       !
964       ! This adjusts the values of Xmin and Xmax
966       !
968 Set_x_scales:                                       !Check for 0 value
970       IF Xmax<>0 THEN
972         Maxpower=INT(LGT(ABS(Xmax)))
974         Maxmantissa=10^FRACT(LGT(ABS(Xmax)))
976         IF Xmax<0 THEN
978           Maxmantissa=-1*Maxmantissa
980         END IF
982       ELSE
984         Maxpower=1
986         Maxmantissa=0
988       END IF
990       IF Xmin<>0 THEN
992         Minpower=INT(LGT(ABS(Xmin)))
994         Minmantissa=10^FRACT(LGT(ABS(Xmin)))
996         IF Xmin<0 THEN
998           Minmantissa=-1*Minmantissa
1000        END IF
1002      ELSE
1004        Minpower=0
1006        Minmantissa=0
1008      END IF
1010      !
1012      Signsum=SGN(Xmax)+SGN(Xmin)                   !SELECT the sum of the
1014      SELECT Signsum                                !signs of Xmax and Xmin
1016      CASE 2,1                                      ! CASE both positive, or
1018        Minmantissa=0                               ! one positive, one zero
1020        I=0
1022        LOOP
1024          I=I+1
1026          IF Maxmantissa<I THEN
1028            Maxmantissa=I
1030          END IF
1032        EXIT IF Maxmantissa=I
1034        END LOOP
1036      CASE -2,-1                                    ! CASE both negative, or
1038        Maxmantissa=0                               ! one negative, one zero
1040        I=0
1042        LOOP
1044          I=I-1
1046          IF Minmantissa>I THEN
1048            Minmantissa=I
1050          END IF
1052        EXIT IF Minmantissa=I
1054        END LOOP
1056      CASE 0                                        ! CASE one negative,
1058        I=0                                         ! one positive
1060        LOOP
1062          I=I+1
1064          IF Maxmantissa<I THEN
1066            Maxmantissa=I
1068          END IF
1070        EXIT IF Maxmantissa=I
1072        END LOOP
1074        I=0
1076        LOOP
1078          I=I-1
1080          IF Minmantissa>I THEN
```

```
1090        IF Maxpower>Minpower THEN
1092          Minmantissa=-1.0
1094          Minpower=Maxpower
1096        END IF
1098        IF Minpower>Maxpower THEN
1100          Maxmantissa=1.0
1102          Maxpower=Minpower
1104        END IF
1106      CASE ELSE
1108        PRINT "SIGNSUM INCORRECT"
1110        PAUSE                                        !
1112      END SELECT
1114      Xmax=Maxmantissa*10^Maxpower
1116      Xmin=Minmantissa*10^Minpower
1118      GOSUB X_limits
1120      GOTO Satisfied
1122      !
1124      ! Set Xtick, Xmajor, Xvalues (Subroutine)
1126      !
1128 X_limits:                                         !
1130      IF Range_calc=0 THEN
1132        Xrange=10^FRACT(LGT(ABS(Xmax-Xmin)))
1134      END IF
1136      IF Xrange<>0 THEN
1138 !      IF Auto<>-1 THEN PRINT TABXY(25,1);"Range=";Xrange
1140        Xtick=Tick_array(Xrange)
1142        Xmajor=Major_array(Xrange)
1144        Xvalues=Value_array(Xrange)
1146      ELSE
1148        PRINT "RANGE=0:  error in Auto_scale subprogram (Set_x_scales)"
1150        PAUSE
1152      END IF
1154      RETURN
1156      !
1158 Satisfied:                                        !Display values
1160      IF Auto=(-1) THEN GOTO End_auto_scale
1162      GRAPHICS OFF
1164      Clear_screen
1166      PRINT TABXY(0,1);"X-axis maximum=";Xmax;"       ";TABXY(40,1);"Range=";Xr
1168      PRINT TABXY(0,2);"X-axis minimum=";Xmin;"       "
1170      PRINT TABXY(0,3);"There are";Xtick;"ticks, each";(Xmax-Xmin)/Xtick;"unit
1172      PRINT TABXY(0,4);"Every";Xmajor;"ticks there's a major tick.     "
1174      PRINT TABXY(0,5);"There are";Xvalues;"values on the axis.      "
1176      PRINT TABXY(0,8);"Y-axis maximum=";Ymax;"       ";TABXY(40,8);"Range=";Yr
1178      PRINT TABXY(0,9);"Y-axis minimum=";Ymin;"   "
1180      PRINT TABXY(0,10);"There are";Ytick;"ticks, each";(Ymax-Ymin)/Ytick;"uni
1182      PRINT TABXY(0,11);"Every";Ymajor;"ticks there's a major tick.     "
1184      PRINT TABXY(0,12);"There are";Yvalues;"values on the axis.      "
1186      !
1188      ! If correct, continue.  If (R)ecalc, then calculate Xtick, etc.
1190      ! If (C)hange range, then calculate Xtick, etc. without calc. range.
1192      !
1194      Keys_on
1196      ON KEY 0 LABEL "               ",3 GOTO Loope_start
1198      ON KEY 1 LABEL " Cont.         ",3 GOTO No_changes
1200      ON KEY 2 LABEL "Change values  ",3 GOTO Change_values
1202      ON KEY 3 LABEL "Recalc.        ",3 GOTO Recalc
1204      ON KEY 4 LABEL "Change  range  ",3 GOTO Change_range
1206      ON KEY 5 LABEL "Set to window  ",3 GOTO Set_to_window
```

```
1208    ON KEY 6 LABEL "                " GOTO Loope_start
1210    ON KEY 7 LABEL "                " GOTO Loope_start
1212    ON KEY 8 LABEL "                " GOTO Loope_start
1214    ON KEY 9 LABEL "                " GOTO Loope_start
1216    IF Computer$<>"9816" THEN
1218      ON KEY 1 LABEL " Cont.          ",3 GOTO No_changes
1220      ON KEY 3 LABEL "Recalc.         ",3 GOTO Recalc
1222    END IF
1224    !
1226 Loope_start:                                   !
1228    GOTO Loope_start
1230    !
1232 Recalc:                                        !
1234    GOSUB Y_limits
1236    GOSUB X_limits
1238    GOTO Satisfied          !??????
1240    !
1242 Set_to_window:                                 !
1244    Xmin=Start_time
1246    Xmax=Stop_time
1248    GOSUB X_limits
1250    GOTO Satisfied          !??????
1252    !
1254 Change_range:                                  !
1256    PRINT TABXY(40,1);"Range=";CHR$(129);Xrange;CHR$(128)
1258    INPUT "Range= ",Xrange
1260    PRINT TABXY(40,1);"Range=";Xrange;"    "
1262    PRINT TABXY(40,8);"Range=";CHR$(129);Yrange;CHR$(128)
1264    INPUT "Range= ",Yrange
1266    PRINT TABXY(40,8);"Range=";Yrange;"    "
1268    Range_calc=1
1270    GOSUB Y_limits
1272    GOSUB X_limits
1274    Range_calc=0
1276    GOTO Satisfied  !??????
1278    !
1280    ! Change the values for Xmin, etc. manually
1282    !
1284 Change_values:                                 !
1286    Inv$=CHR$(129)
1288    Nor$=CHR$(128)
1290    PRINT TABXY(0,1);"X-axis maximum=";Inv$;Xmax;Nor$
1292    INPUT "Xmax = ",Xmax
1294    PRINT TABXY(0,1);"X-axis maximum=";Xmax;"       "
1296    PRINT TABXY(40,1);"Range=";Xrange
1298    PRINT TABXY(0,2);"X-axis minimum=";Inv$;Xmin;Nor$
1300    INPUT "Xmin = ",Xmin
1302    PRINT TABXY(0,2);"X-axis minimum=";Xmin;"       "
1304    PRINT TABXY(0,3);"There are";Inv$;Xtick;Nor$;"ticks, each";(Xmax-Xmin)/X
1306    INPUT "Xtick = ",Xtick
1308    PRINT TABXY(0,3);"There are";Xtick;"ticks, each";(Xmax-Xmin)/Xtick;"unit
1310    PRINT TABXY(0,4);"Every";Inv$;Xmajor;Nor$;"ticks there's a major tick."
1312    INPUT "Xmajor = ",Xmajor
1314    PRINT TABXY(0,4);"Every";Xmajor;"ticks there's a major tick.   "
1316    PRINT TABXY(0,5);"There are";Inv$;Xvalues;Nor$;"values on the axis."
1318    INPUT "Xvalues = ",Xvalues
1320    PRINT TABXY(0,5);"There are";Xvalues;"values on the axis.         "
1322    PRINT TABXY(0,8);"Y-axis maximum=";Inv$;Ymax;Nor$
1324    INPUT "Ymax = ",Ymax
1326    PRINT TABXY(0,8);"Y-axis maximum=";Ymax;"       "
```

```
1328     PRINT TABXY(40,8);"Range=";Yrange
1330     PRINT TABXY(0,9);"Y-axis minimum=";Inv$;Ymin;Nor$
1332     INPUT "Ymin = ",Ymin
1334     PRINT TABXY(0,9);"Y-axis minimum=";Ymin;"          "
1336     PRINT TABXY(0,10);"There are";Inv$;Ytick;Nor$;"ticks, each";(Ymax-Ymin)/
1338     INPUT "Ytick = ",Ytick
1340     PRINT TABXY(0,10);"There are";Ytick;"ticks, each";(Ymax-Ymin)/Ytick;"uni
1342     PRINT TABXY(0,11);"Every";Inv$;Ymajor;Nor$;"ticks there's a major tick."
1344     INPUT "Ymajor = ",Ymajor
1346     PRINT TABXY(0,11);"Every";Ymajor;"ticks there's a major tick.    "
1348     PRINT TABXY(0,12);"There are";Inv$;Yvalues;Nor$;"values on the axis."
1350     INPUT "Yvalues = ",Yvalues
1352     PRINT TABXY(0,12);"There are";Yvalues;"values on the axis.          "
1354     GOTO Satisfied  !??????
1356     !
1358 No_changes:                                          !
1360     Keys_off
1362     Clear_screen
1364     !
1366 End_auto_scale:                                      !
1368   SUBEND
1370   !____________________________________________________________________________
1372 Auto_seq:SUB Auto_seq(Sequence$(*))
1374   !
1376   ! This subprogram executes an automatic sequence as a series of
1378   ! commands (one per row of Sequence$(*)).
1380   !
1382   ! Available commands are summarized individually below, just before
1384   ! the code that executes that particular command.
1386   !
1388   ! A softkey menu upon entering the routine allows the user to start
1390   ! the sequence, stop it, or resume from where it was stopped before.
1392   ! If the stop key is pressed, the command presently being executed
1394   ! is completed, then the subprogram is exited.
1396   !
1398   ! If the input Sequence$ consists of only one command, the menu is
1400   ! skipped and the command executed directly (this is essential to
1402   ! allow automatic sending of the last plot to an external plotter).
1404   !
1406   ! Commands are in one of the forms:
1408   !          (VERB)
1410   !          (VERB)_(OBJECT)
1412   !          (VERB)_(OBJECT1)_(OBJECT2)
1414   ! For example, to plot channel FJR101 on the top and FJR102 on the
1416   ! bottom of a splitscreen plot, the command would be:
1418   !          PLSS_FJR101_FJR102
1420   !
1422   ! Calculation modules can be executed directly by using their
1424   ! designation as the VERB.
1426   ! The underline character is reserved for use as a separator.
1428   !
1430   ! The structure used to interpret and execute the commands is
1432   ! essentially a series of nested SELECT..CASE..END SELECTs.
1434   !
1436   ! The After_plot subroutine, executed after (almost) every type
1438   ! of plot, allows plots to be dumped to a printer or plotted,
1440   ! according to the variable
1442   !
1444   !          Auto_dump - specifies action to be taken after a plot:
1446   !                        0 - Wait for user to press ENTER.
```

```
1448 !                          1 - Dump plot to graphics printer.
1450 !                         -1 - Re-execute the last command, except plot
1452 !                              it on an external plotter.
1454 !
1456 ! The variables
1458 !          Auto_scale
1460 !          Skip
1462 !          No_avg
1464 ! are all stored away temporarily while an automatic sequence is
1466 ! being executed and returned to their former values when the
1468 ! sequence is completed (or stopped).This is done to avoid user
1470 ! interaction during the sequence execution.
1472 !========================================================================
1474   OPTION BASE 1
1476   COM /Raw_defaults/ INTEGER No_avg,Skip,REAL Start_time,Stop_time
1478   COM /Buff_defaults/ Buff_ingain
1480   COM /Graph_stuff/ Color(*),Line(*),Overlay_no,Full_screen,Split_format,A
1482   COM /Graph_limits/ Viewxmin,Viewxmax,Viewymin,Viewymax,Xmin,Xmax,Ymin,Ym
1484   COM /Msus/ Msus_raw1$,Msus_raw2$,Msus_buff$,Msus_ext$,Test_hdr$
1486   COM /Hardware/ Prt_address,Current_prt,Computer$
1488   COM /Autosequence/ INTEGER Seq_no,Seq_flag,Autosequence$(*)
1490   !------------------------------------------------------------------------
1492   INTEGER I,Flag,Flag1,Flag2,Interrupt
1494   DIM Module$[10],Plot_no$[2],Seq2$(1)[20]
1496   !
1498   Interrupt=0
1500   Start_of_seq=1
1502   !*
1504   !*If only one command, execute it without going through the menu.
1506   !*
1508   IF SIZE(Sequence$,1)=1 THEN GOTO Start_seq
1510 Auto_seq_menu:                                              !
1512   OFF KEY
1514   ON KEY 0 LABEL "Auto =>Plotter",2 GOSUB Auto_plotter
1516   ON KEY 1 LABEL "Auto =>Printer",2 GOSUB Auto_printer
1518   ON KEY 2 LABEL "Disable Auto  ",2 GOSUB Auto_disable
1520   ON KEY 3 LABEL "              ",1 GOTO Start_loop
1522   ON KEY 4 LABEL "              ",1 GOTO Start_loop
1524   ON KEY 5 LABEL "START         ",2 GOTO Start_seq
1526   ON KEY 6 LABEL " STOP         ",14 GOSUB Interrupt_seq
1528   ON KEY 7 LABEL "RESUME        ",2 GOTO Resume_seq
1530   ON KEY 8 LABEL " EXIT         ",2 GOTO End_auto
1532   ON KEY 9 LABEL "              ",1 GOTO Start_loop
1534   !
1536   DISP "Auto sequence"
1538   !
1540 Start_loop:                                                 !
1542   GOTO Start_loop
1544   !
1546 Auto_plotter:                                               !
1548   Auto_dump=-1
1550   PRINT "All plots during the sequence will now be dumped to the plotter."
1552   RETURN
1554   !
1556 Auto_printer:                                               !
1558   Auto_dump=1
1560   PRINT "All plots during the sequence will now be dumped to the printer"
1562   RETURN
1564   !
1566 Auto_disable:                                               !
```

```
1566    Auto_dump=0
1570    PRINT "Auto dump feature disabled"
1572    RETURN
1574    !
1576 Resume_seq:                                 !
1578    Start_of_seq=Seq_no+1
1580    GOTO Start_seq
1582    !
1584 Start_seq: !
1586    Auto_temp=Auto_scale
1588    Skip_temp=Skip
1590    No_avg_temp=No_avg
1592    Auto_scale=-1
1594    No_avg=-1
1596    Skip=-1
1598    !*
1600    !*Start of Sequence execution
1602    !*
1604    FOR Seq_no=Start_of_seq TO SIZE(Sequence$,1)
1606      Seq_flag=1
1608      I=Seq_no
1610      PRINT
1612      PRINT CHR$(129);"Executing module: ";Sequence$(I);" ";CHR$(128)
1614      PRINT
1616      Row=0
1618      Divver1=0
1620      Divver2=0
1622      No_divs=0
1624      Errflag=0
1626      Errplot=0
1628      Plot_no=0
1630      !*
1632      !* Find position of _ chars.
1634      !*
1636      Divver1=POS(Sequence$(I),"_")
1638      IF Divver1>0 THEN
1640        No_divs=1
1642        Divver2=POS(Sequence$(I)[Divver1+1],"_")
1644        IF Divver2>0 THEN
1646          Divver2=Divver2+Divver1
1648          No_divs=2
1650        END IF
1652      END IF
1654      !
1656      SELECT No_divs
1658      CASE 0
1660        SELECT UPC$(Sequence$(I))
1662        CASE "PRTP"                              !Direct o/p to printer
1664          Current_prt=Prt_address
1666        CASE "PRTC"                              !Direct o/p to screen
1668          Current_prt=CRT
1670        CASE "CLSC"                              !Clear screen
1672          Clear_screen
1674        CASE "PAWS"                              !Wait for key
1676          BEEP 200,.1
1678          Wait_for_key
1680        CASE ELSE
1682          Exec_module(Sequence$(I),Flag,Row)
1684        END SELECT  ! SEQUENCE$(I)
1686      CASE 1
```

```
1688  !------------------------------------------!
1690  ! 1 VERB, 1 OBJECT                         !
1692  !------------------------------------------!
1694    Verb$=UPC$(Sequence$(I)[1,Divver1-1])
1696    Object1$=UPC$(Sequence$(I)[Divver1+1])
1698    !-----------------------------!
1700    !  Decode if splitscreen plot !
1702    !-----------------------------!
1704    IF LEN(Verb$)>4 THEN
1706      Plot_no$=Verb$[5,5]
1708      IF Plot_no$="1" OR Plot_no$="2" THEN
1710        Plot_no=VAL(Plot_no$)
1712      ELSE
1714        PRINT "Don't understand ";Verb$
1716        Plot_no=0
1718      END IF
1720    ELSE
1722      Plot_no=0
1724    END IF
1726    !
1728    SELECT Verb$[1,4]
1730    !*
1732    !* "PLOT"  : 1 variable  vs. Time
1734    !* "PLOT1" : screen 1
1736    !* "PLOT2" : screen 2
1738    !*
1740    CASE "PLOT"
1742      Exec_module(Object1$,Flag,Row)
1744      SELECT Flag
1746      CASE 1
1748        Plot_raw(Plot_no,Row,Object1$,No_avg,Skip,Start_time,Stop_time)
1750        GOSUB After_plot
1752      CASE 0,2
1754        Plot_buff(Plot_no,Row,Object1$)
1756        GOSUB After_plot
1758      CASE ELSE
1760        PRINT "Nothing to plot."
1762      END SELECT !flag
1764      !--------------------------------------!
1766      !  "PLIN" plot integer raw data        !
1768      !--------------------------------------!
1770    CASE "PLIN"
1772      Exec_module(Object1$,Flag,Row)
1774      IF Flag=1 THEN
1776        Plot_int_raw(0,Row,Object1$,No_avg,Skip,0,Start_time,Stop_time)
1778      ELSE
1780        PRINT "Cannot plot integer ";Object1$
1782      END IF
1784      !--------------------------------------!
1786      !  "OVLY": overlay 1 variable vs. Time !
1788      !   (no dump graphics after plotting)  !
1790      !--------------------------------------!
1792    CASE "OVLY"
1794      Exec_module(Object1$,Flag,Row)
1796      SELECT Flag
1798      CASE 1
1800        Overlay_raw(Row,Object1$,No_avg,Skip,Start_time,Stop_time)
1802      CASE 0,2
1804        Overlay_buff(Row,Object1$)
1806      CASE ELSE
```

```
1808          PRINT "Nothing to plot."
1810        END SELECT !flag
1812        !------------------------------------!
1814        !  "COPY"                            !
1816        !      (same name - replace duplicate) !
1818        !                                    !
1820        !  COPY_(channel) 1 raw file to buffer !
1822        !  COPY_RAW : all raw files to buffers !
1824        !  COPY_BUFF: all buffers to external  !
1826        !------------------------------------!
1828      CASE "COPY"
1830        SELECT Object1$
1832        CASE "RAW"
1834          Copy_all(0)
1836        CASE "BUFF"
1838          Copy_all(1)
1840        CASE ELSE
1842          Exec_module(Object1$,Flag,Row)
1844          IF Flag=1 THEN
1846            Raw_to_buff(Row,Object1$,Object1$,No_avg,Skip,Start_time,Stop_
1848          ELSE
1850            PRINT "Raw file ";Object1$;" not found to COPY"
1852          END IF!(Flag)
1854        END SELECT !object1$
1856        !------------------------------------!
1858        !  STAT_(channel) :list stats of channel
1860        !  STAT_FILE : create stats file from raw data
1862        !  STAT_READ : read and print stats file
1864        !  STAT_RAW  : list stats of raw data
1866        !  STAT_BUFF : list stats of buffer data
1868        !------------------------------------!
1870      CASE "STAT"
1872        SELECT Object1$
1874        CASE "FILE"
1876          Write_stats(1,Test_hdr$&"STATS",1)
1878        CASE "READ"
1880          Read_stats(Test_hdr$&"STATS")
1882        CASE "RAW"
1884          Statistics(0,"ALL",1)
1886        CASE "BUFF"
1888          Statistics(0,"ALL",2)
1890        CASE ELSE
1892          Exec_module(Object1$,Flag,Row)
1894          SELECT Flag
1896          CASE 1
1898            Statistics(Row,Object1$,1)
1900          CASE 0,2
1902            Statistics(Row,Object1$,2)
1904          CASE ELSE
1906            PRINT "Cannot do STAT"
1908          END SELECT! (Flag)
1910        END SELECT  ! (Object1$)
1912        !------------------------------------!
1914        !  Undefined verb:                   !
1916        !  Execute calc module with input    !
1918        !------------------------------------!
1920      CASE ELSE
1922        Stat=1
1924        Calc_modules(Verb$,Stat,Object1$)
1926        IF Stat<>0 AND Stat<>3 THEN PRINT "Calc module ";Verb$;" not found
```

```
1928        END SELECT     !  verb$
1930      CASE 2
1932      !----------------------------------------------------------!
1934      ! 1 VERB, 2 OBJECTS                                        !
1936      !                                                          !
1938      !----------------------------------------------------------!
1940        Verb$=UPC$(Sequence$(I)[1,Divver1-1])
1942        Object1$=UPC$(Sequence$(I)[Divver1+1,Divver2-1])
1944        Object2$=UPC$(Sequence$(I)[Divver2+1])
1946        PRINT "verb,object1,object2=";Verb$,Object1$,Object2$
1948        !-----------------------------!
1950        !  Decode if splitscreen plot !
1952        !-----------------------------!
1954        IF LEN(Verb$)>4 THEN
1956          Plot_no$=Verb$[5,5]
1958          IF Plot_no$="1" OR Plot_no$="2" THEN
1960            Plot_no=VAL(Plot_no$)
1962          ELSE
1964            PRINT "Don 't understand ";Verb$
1966            Plot_no=0
1968          END IF
1970        ELSE
1972          Plot_no=0
1974        END IF
1976        SELECT Verb$[1,4]
1978      !--------------------------------------!
1980      ! COPY: copy raw to buff, different name
1982      !--------------------------------------!
1984        CASE "COPY"
1986          Check_index(1,Object1$,Row)
1988          IF Row>0 THEN
1990            Raw_to_buff(Row,Object1$,Object2$,No_avg,Skip,Start_time,Stop_ti
1992          ELSE
1994            PRINT "Cannot find Raw ";Object1$;" to copy"
1996          END IF ! (row)
1998      !--------------------------------------!
2000      ! PLOV: Plot Overlay                   !
2002      !       (plot Obj 1, overlay Obj 2)    !
2004      ! (equiv. to PLOT_CH1, OVLY_CH2)       !
2006      ! PLOV1:     screen 1                  !
2008      ! PLOV2:     screen 2                  !
2010      !--------------------------------------!
2012        CASE "PLOV"
2014          Exec_module(Object1$,Flag,Row1)
2016          Errflag=0
2018          SELECT Flag
2020          CASE 1
2022            Plot_raw(Plot_no,Row1,Object1$,No_avg,Skip,Start_time,Stop_time)
2024          CASE 0,2
2026            Plot_buff(Plot_no,Row1,Object1$)
2028          CASE ELSE
2030            PRINT "Cannot find ";Object1$;" to plot,cannot overlay ";Object2
2032            Errflag=1
2034          END SELECT ! (Flag)
2036          IF Errflag=0 THEN
2038            Exec_module(Object2$,Flag,Row2)
2040            SELECT Flag
2042            CASE 1
2044              Overlay_raw(Row2,Object2$,No_avg,Skip,Start_time,Stop_time)
2046              GOSUB After_plot
```

```
2048          CASE 0,2
2050            Overlay_buff(Row2,Object2$)
2052            GOSUB After_plot
2054          CASE ELSE
2056            PRINT "Cannot find ";Object2$;" to overlay."
2058          END SELECT! (flag)
2060        END IF ! (Errflag)
2062        !---------------------------------------!
2064        !  PLXY : Plot Obj1 (y) vs. Obj2(x)     !
2066        !  PLXY1 :                              !
2068        !  PLXY2 :                              !
2070        !---------------------------------------!
2072      CASE "PLXY"
2074        Errflag=0
2076        Exec_module(Object1$,Flag1,Row1)
2078        SELECT Flag1
2080        CASE 1
2082          Raw_to_buff(Row1,Object1$,Object1$,No_avg,Skip,Start_time,Stop_t
2084        CASE 0,2
2086          !      I'm all right Jack.
2088        CASE ELSE
2090          Errflag=1
2092        END SELECT ! (Flag1)
2094        IF Errflag=0 THEN
2096          Exec_module(Object2$,Flag2,Row2)
2098          SELECT Flag2
2100          CASE 1
2102            Raw_to_buff(Row2,Object2$,Object2$,No_avg,Skip,Start_time,Stop
2104          CASE 0,2
2106            !  good enough
2108          CASE ELSE
2110            Errflag=1
2112          END SELECT! (Flag2)
2114        END IF !(Errflag)
2116        IF Errflag=0 THEN
2118          Plot_buff_1vs2(Plot_no,Row1,Object1$,Row2,Object2$,Errplot)
2120          IF Errplot=0 THEN GOSUB After_plot
2122        END IF                                  ! (Errflag)
2124        !---------------------------------------!
2126        ! PLSS : Plot splitsceen
2128        !    (Channel 1 on 1, channel 2 on 2)   !
2130        !    (equiv. to PLOT1_CH1, PLOT2_CH2)   !
2132        !---------------------------------------!
2134      CASE "PLSS"
2136        Errflag=0
2138        Exec_module(Object1$,Flag1,Row1)
2140        SELECT Flag1
2142        CASE 1
2144          Plot_raw(1,Row1,Object1$,No_avg,Skip,Start_time,Stop_time)
2146        CASE 0,2
2148          Plot_buff(1,Row1,Object1$)
2150        CASE ELSE
2152          Errflag=1
2154        END SELECT                                ! (flag1)
2156        IF Errflag=0 THEN
2158          Exec_module(Object2$,Flag2,Row2)
2160          SELECT Flag2
2162          CASE 1
2164            Plot_raw(2,Row2,Object2$,No_avg,Skip,Start_time,Stop_time)
2166            GOSUB After_plot
```

```
2168            CASE 0,2
2170              Plot_buff(2,Row2,Object2$)
2172              GOSUB After_plot
2174            CASE ELSE
2176              Errflag=1
2178            END SELECT!flag2
2180          END IF ! (Errflag)
2182 End_plss:                                        !
2184          !--------------------------------------!
2186          !  Verb$ is not known                  !
2188          !--------------------------------------!
2190        CASE ELSE
2192          PRINT "Unknown verb: ";Verb$
2194        END SELECT !verb$
2196      END SELECT   !no_div
2198          !--------------------------------------!
2200          ! Exit if STOP key pressed lately      !
2202          !--------------------------------------!
2204      IF Interrupt=1 THEN GOTO Seq_stopped
2206    NEXT Seq_no                                   ! (next command)
2208    !-----------------------------!
2210    ! Normal termination of seq
2212    !-----------------------------!
2214    Seq_no=0
2216    GOTO End_auto
2218    !
2220 After_plot:                                      !After plot subroutine
2222    IF Interrupt=1 THEN GOTO Seq_stopped
2224    SELECT Auto_dump
2226    CASE 0                                        !Wait for user to press
2228      BEEP                                        !key
2230      Wait_for_key
2232    CASE 1                                        !Dump to printer
2234      ON TIMEOUT 7,1 GOTO Done_dump
2236      DUMP GRAPHICS
2238      GOTO Done_dump
2240 Dump_timeout:PRINT "Cannot dump plot; printer timeout!"
2242 Done_dump:                                       !
2244      OFF TIMEOUT 7
2246    CASE -1                                       !Replot with ext. plotter
2248 Replot_ext:                                      !
2250      INPUT "Is Plotter ready to plot?",Ans$
2252      IF UPC$(Ans$[1,1])="Y" THEN
2254        ON TIMEOUT 7,1 RECOVER No_plotter
2256        OUTPUT 705;"OS"
2258        OFF TIMEOUT
2260        Chg_plotter("705")
2262        Auto_dump=0                               !Temporarily disable
2264        Seq2$(1)=Sequence$(I)                     !before
2266        Auto_seq(Seq2$(*))                        !Recursive call to send to
2268        DISP                                      !plotter
2270      END IF
2272      Auto_dump=-1
2274 Done_plot:                                       !
2276      Chg_plotter("CRT")
2278    END SELECT
2280    ALPHA ON
2282    GRAPHICS OFF
2284    RETURN
2286    !
```

```
2288 Interrupt_seq:                                         !
2290    Interrupt=1
2292    RETURN
2294    !
2296 Seq_stopped:                                           !
2298    PRINT "Sequence terminated at your request"
2300    GOTO End_auto
2302    !
2304 End_auto:                                              !
2306    PRINT
2308    Seq_flag=0
2310    Auto_scale=Auto_temp
2312    Skip=Skip_temp
2314    No_avg=No_avg_temp
2316    ALPHA ON
2318    GRAPHICS OFF
2320    PRINT "Done automatic sequence."
2322    SUBEXIT
2324    !++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
2326 No_plotter:                                            !
2328    Clear_screen
2330    BEEP
2332    WAIT .1
2334    BEEP
2336    INPUT "I cannot find the plotter anywhere. Have you seen it?",Ans$
2338    IF UPC$(Ans$[1,1])="Y" THEN
2340      GOTO Replot_ext
2342    ELSE
2344      GOSUB Auto_disable
2346      GOTO Done_plot
2348    END IF
2350    !
2352 End_auto_seq:                                          !
2354  SUBEND
2356  !______________________________________________________________________
2358 Avg_press:SUB Avg_press
2360  !
2362  ! This is an example of a calculation module that has one input dataset.
2364  ! The output is stored in a disk data buffer called PAVG (note that
2366  ! name is identical to the calculation module designator).
2368  ! This module will not be used for the present application.
2370  !======================================================================
2372    OPTION BASE 1
2374    COM /Accumulators/ No_acc,Size_acc,Acc1(*),Acc2(*),Acc3(*),Acc4(*),Acc5(
2376    COM /Raw_defaults/ INTEGER No_avg,Skip,REAL Start_time,Stop_time
2378    COM /Buff_defaults/ Buff_ingain
2380    !--------------------------------------------------------------------
2382    Raw_to_acc(0,"P3",3,No_avg,Skip,Start_time,Stop_time)
2384    Raw_to_acc(0,"P2",2,No_avg,Skip,Start_time,Stop_time)
2386    Raw_to_acc(0,"P1",1,No_avg,Skip,Start_time,Stop_time)
2388    MAT Acc1= Acc1+Acc2
2390    MAT Acc1= Acc1+Acc3
2392    MAT Acc1= Acc1/(3)
2394    Acc_to_buff(1,"PAVG","Average Pressure","Pressure (kPa)",Buff_ingain,0)
2396  SUBEND
2398  !______________________________________________________________________
2400 Buff_to_acc:SUB Buff_to_acc(Row,Id$,Accum_no)
2402  !
2404  !  Transfers data directly from buffer (Id$) to accumulator (Accum_no)
2406  !======================================================================
2408    OPTION BASE 1
2410    ALLOCATE Tempdata(FNSize_acc)
2412    !
2414    IF Row=-1 THEN SUBEXIT
2416    Buff_to_temp(Row,Id$,Tempdata(*))
2418    IF Row=-1 THEN SUBEXIT
2420    Temp_to_acc(Tempdata(*),Accum_no)
2422    !
2424    DEALLOCATE Tempdata(*)
2426  SUBEND
2428  !______________________________________________________________________
2430 Buff_to_ext:SUB Buff_to_ext(Source_id$,Ext_id$)
2432  !
2434  ! This copies a buffer file to an external mass storage
2436  ! file for data interchange or condensed storage.
2438  ! Ext_id$ is appended to Msus_ext$ to form the filename.
2440  ! Source_id$ is the buffer designation.
2442  !======================================================================
2444    OPTION BASE 1
2446    COM /Index_string/ Buff_id$(*),Buff_title$(*),Buff_units$(*)
2448    COM /Index_real/ Buff_freq(*),Buff_gain(*),Buff_offset(*),Buff_time(*)
2450    COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
2452    COM /Msus/ Msus_raw1$,Msus_raw2$,Msus_buff$,Msus_ext$,Test_hdr$
2454    COM /Buff_defaults/ Buff_ingain
2456    COM /Raw_defaults/ INTEGER No_avg,Skip,REAL Start_time,Stop_time
2458    !--------------------------------------------------------------------
2460    INTEGER Flag
2462    ALLOCATE Buffdata(FNSize_acc)
2464    ALLOCATE INTEGER Intdata(FNSize_acc)
2466    !
2468    Source_id$=UPC$(Source_id$)
2470    Ext_id$=UPC$(Ext_id$)
2472    !
2474    Exec_module(Source_id$,Flag,Row)
2476    !
2478    SELECT Flag
2480    CASE 1
2482      Raw_to_buff(Row,Source_id$,Source_id$,No_avg,Skip,Start_time,Stop_time
2484    CASE 0,2
2486    CASE ELSE
2488      PRINT "Cannot find ";Source_id$
2490      GOTO Endofit
2492    END SELECT
2494    !
2496    Check_index(2,Source_id$,Row) !{{{
2498    Buff_to_temp(Row,Source_id$,Buffdata(*))
2500    Data_pts=SIZE(Buffdata,1)
2502    !
2504    DISP "Integerizing data..."
2506    Data_max=MAX(Buffdata(*))
2508    Data_min=MIN(Buffdata(*))
2510    Gain=(Data_max-Data_min)/65535
2512    Offset=32767-Data_max/Gain
2514    MAT Buffdata= Buffdata/(Gain)
2516    MAT Intdata= Buffdata+(Offset)
2518    DISP
2520    !-----------------------------!
2522    ! Create file using I.D. name.....
2524    !-----------------------------!
2526 Int_file_create:   !
```

```
2528     ON ERROR GOTO Err_file_create
2530     File_name$=Ext_id$&Msus_ext$
2532     File_size=1.5+INT(Data_pts*2/256)
2534     CREATE BDAT File_name$,File_size
2536     OFF ERROR
2538     !-----------------------------!
2540     ! Write header information    !
2542     !-----------------------------!
2544     ON ERROR GOTO Err_file_write
2546     ASSIGN @File TO File_name$
2548     OUTPUT @File;Buff_id$(Row,2)
2550     OUTPUT @File;Buff_title$(Row,2)
2552     OUTPUT @File;Buff_units$(Row,2)
2554     OUTPUT @File;Buff_freq(Row,2)
2556     OUTPUT @File;Gain
2558     OUTPUT @File;Offset
2560     OUTPUT @File;Buff_time(Row,2)
2562     OUTPUT @File;Data_pts
2564     Event_pointer=Buff_event(Row,2)            ! convert to REAL
2566     OUTPUT @File;Event_pointer
2568     !-----------------------------!
2570     ! Write data                  !
2572     !-----------------------------!
2574 Int_file_write:                  !
2576     OUTPUT @File;Intdata(*)
2578     ASSIGN @File TO *
2580     OFF ERROR
2582     PRINT "External file ";Ext_id$;" created."
2584     !-----------------------------!
2586 Endofit:                         !
2588     DEALLOCATE Intdata(*)
2590     DEALLOCATE Buffdata(*)
2592     SUBEXIT
2594     !-----------------------------!
2596 Err_file_create:                 !
2598     SELECT ERRN
2600     CASE 54
2602       Ans$=""
2604       BEEP
2606       PRINT " -----------------------------"
2608       PRINT " Duplicate external file name"
2610       INPUT "TURF OLD FILE?",Ans$
2612       IF UPC$(Ans$[1,1])="Y" THEN
2614         PURGE File_name$
2616         GOTO Int_file_create
2618       END IF
2620     CASE ELSE
2622       PRINT ERRM$
2624     END SELECT
2626     GOTO Endofit
2628     !-----------------------------!
2630 Err_file_write:                  !
2632     PRINT ERRM$
2634     GOTO Endofit
2636  SUBEND
2638  !____________________________________________________________
2640 Buff_to_temp:SUB Buff_to_temp(Row,Id$,Tempdata(*))
2642  !
2644  !  Transfers data directly from buffer (Id$) to temporary storage
2646  !  It is assumed that Tempdata has been allocated to the size of
```

```
2648  !  the buffer (=FNSize_acc).
2650  !=========================================================================
2652    OPTION BASE 1
2654    COM /Index_string/ Buff_id$(*),Buff_title$(*),Buff_units$(*)
2656    COM /Index_real/ Buff_freq(*),Buff_gain(*),Buff_offset(*),Buff_time(*)
2658    COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
2660    COM /Msus/ Msus_raw1$,Msus_raw2$,Msus_buff$,Msus_ext$,Test_hdr$
2662    !-----------------------------------------------------------------------
2664    Id$=UPC$(Id$)
2666    IF Row=0 THEN
2668      Check_index(2,Id$,Row)
2670      IF Row=0 THEN
2672        Row=-1
2674        PRINT "Cannot find Buffer ";Id$
2676        SUBEXIT
2678      END IF
2680    END IF
2682    !*
2684    !* If gain = 1, then buffer is REAL. Otherwise, it is INT.
2686    !*
2688    IF Buff_gain(Row,2)<>1 THEN                       !Integer entry routine
2690      ALLOCATE INTEGER Intdata(FNSize_acc)
2692      ON ERROR GOTO Err_file
2694      ASSIGN @Infile TO Test_hdr$[1,5]&Id$&Msus_buff$
2696      ON END @Infile GOTO Done_enter
2698      ENTER @Infile;Intdata(*)
2700 Done_enter:                                          !REDIM buff to data size
2702      OFF ERROR
2704      Data_size=FNFile_size(@Infile)/2
2706      REDIM Intdata(Data_size)
2708      MAT Tempdata= Intdata-(Buff_offset(Row,2))
2710      MAT Tempdata= Tempdata*(Buff_gain(Row,2))
2712      DEALLOCATE Intdata(*)
2714    ELSE                                              !REAL entry routine
2716      ON ERROR GOTO Err_file
2718      ASSIGN @Infile TO Test_hdr$&Id$&Msus_buff$
2720      ON END @Infile GOTO Done_real
2722      ENTER @Infile;Tempdata(*)
2724 Done_real:                                           !REDIM buff to data size
2726      OFF ERROR
2728      Data_size=FNFile_size(@Infile)/8
2730      REDIM Tempdata(Data_size)
2732      OFF END @Infile
2734    END IF
2736    SUBEXIT
2738    !++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
2740 Err_file:                                            !
2742    PRINT "Error in loading from buffer ";Id$
2744    IF Input_gain<>1 THEN
2746      PRINT "(Integer)"
2748    ELSE
2750      PRINT "(Real)"
2752    END IF
2754    PRINT ERRM$
2756    PAUSE
2758    DEALLOCATE Intdata(*)
2760  SUBEND
2762  !________________________________________________________________________
2764 Calc_modules:SUB Calc_modules(Module$,Exec_flag,Desc$)
2766  !
```

```
2768  !  This executes or checks for the existence of a calculation module.
2770  !  INPUTS:
2772  !          Module$   - module designation
2774  !          Exec_flag - if 1, execute module if found.
2776  !                      if 0, just check to see if it exists
2778  !          Desc$     - if the calculation module requires an
2780  !                      input string, Desc$ is used.
2782  !  OUTPUTS:
2784  !          Exec_flag - returns:  0 if module found and executed, and
2786  !                      buffer of same name as calc module is created.
2788  !                                1 if module found (not executed).
2790  !                                3 if module found and executed, and
2792  !                     more than one buffer (or no buffers) are created.
2794  !                               -1 if module not found.
2796  !          Desc$     - simple description of module.
2798  !=====================================================================
2800    OPTION BASE 1
2802    COM /Calc_modules/ Module_index$(*),First_calc,No_calcs
2804    !--------------------------------------------------------------------
2806    Input$=Desc$                                   !Save for calc module
2808    !
2810 Calc_data:                                      !
2812    No_calcs=4                                     !Set number calc modules
2814    !----------------------------------!
2816    !   Calculation Module index format:
2818    !    NAME,"DESCRIPTION",EXEC_FLAG
2820    !----------------------------------!
2822    !    Exec_flag=1 if calc module creates one output buffer
2824    !              =3 if output is more than one buffer.
2826    !----------------------------------!
2828    DATA PS,"Principal Strain",3
2830    DATA DEF ,"Deflection (from Acceleration)",3
2832    DATA STRG,"Surface Stress (from gauge)",3
2834    DATA LOAD,"Actuator and Total Loads",3
2836    !
2838    IF First_calc=0 THEN
2840      First_calc=1
2842      RESTORE Calc_data
2844      REDIM Module_index$(No_calcs,3)
2846      READ Module_index$(*)
2848    END IF
2850    !----------------------------!
2852    ! Check index for calculation module
2854    ! Flag= -1:module not found
2856    !        1:module found,
2858    !----------------------------!
2860 Check:                                          !
2862    Flag=-1
2864    FOR I=1 TO No_calcs
2866      IF Module$=Module_index$(I,1) THEN
2868        Desc$=Module_index$(I,2)
2870        Exec=VAL(Module_index$(I,3))
2872        IF Flag<>-1 THEN PRINT "Duplicate calc module found!"
2874        Flag=Exec
2876      END IF
2878    NEXT I
2880    !
2882 Done_check:                                     !
2884    IF Flag=-1 THEN
2886      Exec_flag=-1
```

```
2888       SUBEXIT
2890     END IF
2892       !----------------------------!
2894       ! Check Exec_flag to see what to do (execute or not?)
2896       ! Change Exec_flag to a different returned value
2898       !          (depending on what is done )
2900       !----------------------------!
2902     SELECT Exec_flag
2904     CASE 0
2906       Exec_flag=1                                  !Found,not executed
2908     CASE 1
2910       IF Flag=1 THEN Exec_flag=0! Found,executed,buffer of same name created
2912       IF Flag=3 THEN Exec_flag=3! Found and executed
2914 Calc_select:
2916       !----------------------------!
2918       ! Calculation module SELECT    !
2920       !----------------------------!
2922       SELECT Module$
2924       CASE "PS"
2926         Principal_e(Input$)
2928       CASE "DEF"
2930         Deflection(Input$)
2932       CASE "STRG"
2934         Stress_gauge(Input$)
2936       CASE "LOAD"
2938         Act_load(Input$)
2940       CASE ELSE
2942         PRINT "Calc Module not found in Calc_modules...."
2944         Exec_flag=-1
2946       END SELECT
2948     END SELECT
2950   SUBEND
2952   !______________________________________________________________________
2954 Check_index:SUB Check_index(Ind,Id$,Row)
2956   !
2958   ! Check index for existence of buffer Id$
2960   ! Inputs:
2962   !    Ind: 2 for disk data buffers
2964   !         1 for raw data buffers
2966   !    Id$: Channel identifier
2968   !
2970   ! Returns:
2972   !    Row -set to 0 if buffer ID does not currently exist
2974   !        -set to row of data in index if it does
2976   !======================================================================
2978     OPTION BASE 1
2980     COM /Index_string/ Buff_id$(*),Buff_title$(*),Buff_units$(*)
2982     COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
2984     !--------------------------------------------------------------------
2986     INTEGER I
2988     !
2990     Row=0
2992     FOR I=1 TO No_buffers(Ind)
2994       IF Buff_id$(I,Ind)=Id$ THEN
2996         IF Row>0 THEN
2998           PRINT "Oh! Indications are that this buff is duplicated"
3000           PAUSE
3002         ELSE
3004           Row=I
3006         END IF
```

```
3008       END IF
3010     NEXT I
3012   SUBEND
3014   !________________________________________________________________________
3016 Chg_plotter:SUB Chg_plotter(Plotter$)
3018   !
3020   !  Chg_plotter                           Last_mod: 02/08/86
3022   !
3024   !  Purpose: to allow for other plotters and paper sizes.
3026   !
3028   !  This sets the plotter to the device passed when called.
3030   !
3032   ! Parameters accepted:
3034   !        "OTHER", "CURRENT", "CRT", "704", "705", "705A", "705B"
3036   !
3038   ! Sets the current plotter as follows:
3040   !    If Plotter$ = OTHER   - changes to the other setting.
3042   !                            (if CRT, changes to 705)
3044   !                            (if not CRT, changes to CRT)
3046   !    If Plotter$ = CURRENT - initializes to current setting.
3048   !    If Plotter$ = CRT     - changes the plotter to the CRT.
3050   !    If Plotter$ = 704     - changes to the external plotter at address
3052   !                            704, assuming the 7470A plotter.
3054   !    If Plotter$ = 705     - changes to the external plotter at address
3056   !                            705, either 7470A or 7475A plotter.
3058   !    If Plotter$ = 705:A   - changes to the external plotter at address
3060   !                            705, must be 7475A, on 8.5 x 11 paper.
3062   !    If Plotter$ = 705:B   - changes to the external plotter at address
3064   !                            705, must be 7475a, on 11 x 17 paper.
3066   !
3068   !========================================================================
3070     OPTION BASE 1
3072     Back=0
3074     IF Plotter$="CURRENT" THEN Back=1
3076     !
3078 Start:                                           !
3080     SELECT Plotter$
3082     CASE "OTHER"
3084       IF SYSTEM$("PLOTTER IS")="3" OR SYSTEM$("PLOTTER IS")="6" THEN
3086         DISP "Setting plot device to external plotter."
3088         ON TIMEOUT 7,10 GOTO No_plotter
3090         PLOTTER IS 705,"HPGL"
3092         OUTPUT 705;"SP"
3094         OFF TIMEOUT
3096         OUTPUT 705;"IN,SP"
3098       ELSE
3100         PLOTTER IS CRT,"INTERNAL"
3102         DISP "Setting plot device to CRT."
3104       END IF
3106       Back=0
3108     CASE "CURRENT"
3110       Id$=SYSTEM$("PLOTTER IS")
3112       IF Id$=VAL$(CRT) THEN Plotter$="CRT"
3114       IF Id$="704" THEN Plotter$="704"
3116       IF Id$="705" THEN Plotter$="705"
3118     CASE "CRT"
3120       PLOTTER IS CRT,"INTERNAL"
3122       DISP "Setting plot device to CRT."
3124       Back=0
3126     CASE "704"
```

```
3128      PLOTTER IS 704,"HPGL"
3130      OUTPUT 704;"OI"
3132      ENTER 704;Id$
3134      DISP "Setting plot device to external plotter (704, ";Id$;")"
3136      Back=0
3138    CASE "705"
3140      PLOTTER IS 705,"HPGL"
3142      OUTPUT 705;"OI"
3144      ENTER 705;Id$
3146      DISP "Setting plot device to external plotter (705, ";Id$;")"
3148      Back=0
3150    CASE "705A"
3152      PLOTTER IS 705,"HPGL"
3154      OUTPUT 705;"OI"
3156      ENTER 705;Id$
3158      IF Id$="7475A" THEN
3160        OUTPUT 705;"PS3"
3162        DISP "Setting plot device to external plotter (705, ";Id$;", 8.5"" x
3164      ELSE
3166        DISP "Setting plot device to external plotter (705, ";Id$;")"
3168      END IF
3170      Back=0
3172    CASE "705B"
3174      PLOTTER IS 705,"HPGL"
3176      OUTPUT 705;"OI"
3178      ENTER 705;Id$
3180      IF Id$="7475A" THEN
3182        OUTPUT 705;"PS4"
3184        DISP "Setting plot device to external plotter (705, ";Id$;", 11"" x
3186      ELSE
3188        DISP "Setting plot device to external plotter (705, ";Id$;")"
3190      END IF
3192      Back=0
3194    CASE ELSE
3196      DISP "ERROR: Chg_plotter subprogram - Tried to set to """;Plotter$;""" 
3198      PAUSE
3200    END SELECT
3202    !
3204    IF Back=1 THEN GOTO Start
3206    WAIT 1
3208    SUBEXIT
3210    !+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
3212 No_plotter:                                            !
3214    Ans$="y"
3216    PRINT TABXY(1,19);"PLOTTER not found!?! (check power, cables, etc.)"
3218    DISP CHR$(129)
3220    INPUT " PLOTTER ready? (default is yes) ",Ans$
3222    DISP CHR$(128)
3224    IF UPC$(Ans$[1])="Y" THEN
3226      PRINT TABXY(1,19);RPT$(" ",80)
3228      GOTO Start
3230    ELSE
3232      PRINT TABXY(1,19);RPT$(" ",80)
3234      DISP "Setting plot device to CRT."
3236      PLOTTER IS CRT,"INTERNAL"
3238      WAIT 1
3240    END IF
3242  SUBEND
3244  !______________________________________________________________________
3246  !
```

```
3248 Clear_index:SUB Clear_index(P)
3250  !
3252  ! Clears raw and buffer file index and deletes all buffers from disk.
3254  !=======================================================================
3256    OPTION BASE 1
3258    COM /Index_string/ Buff_id$(*),Buff_title$(*),Buff_units$(*)
3260    COM /Index_real/ Buff_freq(*),Buff_gain(*),Buff_offset(*),Buff_time(*)
3262    COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
3264    COM /Msus/ Msus_raw1$,Msus_raw2$,Msus_buff$,Msus_ext$,Test_hdr$
3266    !----------------------------------------------------------------------
3268    INTEGER I
3270    IF P=2 AND No_buffers(2)<1 THEN
3272      SUBEXIT
3274    END IF
3276    !-----------------------------!
3278    ! Purge buffer files, if applicable.
3280    !-----------------------------!
3282    ON ERROR GOTO Next_purge
3284    IF P=2 THEN
3286      DISP "Purging disk buffer files.."
3288      FOR I=1 TO No_buffers(2)
3290        PURGE Test_hdr$&Buff_id$(I,2)&Msus_buff$
3292 Next_purge:NEXT I
3294    END IF
3296    OFF ERROR
3298    !-----------------------------!
3300    ! Clear half of index         !
3302    !-----------------------------!
3304    FOR I=1 TO No_channels(P)
3306      Buff_id$(I,P)=("$")
3308      Buff_title$(I,P)=("$")
3310      Buff_units$(I,P)=("$")
3312      Buff_freq(I,P)=(-999)
3314      Buff_gain(I,P)=(-999)
3316      Buff_offset(I,P)=(-999)
3318      Buff_points(I,P)=(-999)
3320      Buff_start(I,P)=(-999)
3322      Buff_event(I,P)=(-999)
3324      Buff_end(I,P)=(-999)
3326      No_buffers(P)=0
3328    NEXT I
3330    DISP
3332  SUBEND
3334  !_____________________________________________________________________
3336  SUB Clear_screen
3338 Clear_screen: !
3340    OUTPUT KBD;"K";
3342    GCLEAR
3344  SUBEND
3346  !_______________________________________________________________________!
3348  SUB Copy_all(Mode)
3350 Copy_all: !
3352  !--------------------------------------------!
3354  ! This copies all files from:                !
3356  !         (Mode=0) Raw to Buff               !
3358  !         (Mode=1) Buff to ext (same filename) !
3360  !--------------------------------------------!
3362    OPTION BASE 1
3364    COM /Index_string/ Buff_id$(*),Buff_title$(*),Buff_units$(*)
3366    COM /Index_real/ Buff_freq(*),Buff_gain(*),Buff_offset(*),Buff_time(*)
```

```
3368    COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
3370    COM /Raw_defaults/ INTEGER No_avg,Skip,REAL Start_time,Stop_time
3372    COM /Buff_defaults/ Buff_ingain
3374    COM /Msus/ Msus_raw1$,Msus_raw2$,Msus_buff$,Msus_ext$,Test_hdr$
3376    SELECT Mode
3378    CASE 0
3380      PRINT "Copying all raw files to buffers"
3382      FOR I=1 TO No_buffers(1)
3384        Raw_to_buff(I,Buff_id$(I,1),Buff_id$(I,1),No_avg,Skip,Start_time,Sto
3386      NEXT I
3388      PRINT "Copy complete."
3390    CASE 1
3392      PRINT "Copying all buffers to external files"
3394      FOR I=1 TO No_buffers(2)
3396        Buff_to_ext(Buff_id$(I,2),Test_hdr$&Buff_id$(I,2))
3398      NEXT I
3400      PRINT "Copy complete."
3402    CASE ELSE
3404      PRINT "Unrecognized mode in Copy_all"
3406    END SELECT
3408  SUBEND
3410  !_____________________________________________________________________
3412 Create_index:SUB Create_index
3414  !
3416  !  This creates an index used to access both raw data files
3418  !  and data buffer files.
3420  !
3422  !    Row of each array corresponds to each disk buffer.
3424  !    Index no. =1 for raw data files
3426  !              =2 for data buffer files
3428  !
3430  !    Buff_id$: Channel ID used for filename
3432  !    Buff_title$:   Title of data (for plotting, etc.)
3434  !    Buff_units$:   Description of units of data (e.g. MPa )
3436  !
3438  !    Buff_freq: in Hz. Includes effects of averaging.
3440  !    Buff_gain,Buff_offset:
3442  !            Used to convert the INTEGER storage format
3444  !            of the buffers to Eng. units:
3446  !                 ENG. UNITS = (INTEGER-Buff_offset)*Buff_gain
3448  !             or  INTEGER    = (ENG.UNITS/Buff_gain)+Buff_offset
3450  !            If Buff_gain=1, then storage is REAL in Eng. Units.
3452  !
3454  !    No_buffers:  Current number of disk buffers in use.
3456  !    Buff_points: No. samples in buffer.
3458  !
3460  !    Buff_start, Buff_event, Buff_end:
3462  !                 Sample no. of selected events in time duration.
3464  !                 Normally, -start and -end will only apply to raw.
3466  !
3468  ! For convenience, default parameters for some of these are:
3470  !    Sample_freq : (default for buff_freq)
3472  !    Events(1:3) : (default for Buff_start,Buff_event,Buff_end)
3474  !=====================================================================
3476    OPTION BASE 1
3478    COM /Index_string/ Buff_id$(*),Buff_title$(*),Buff_units$(*)
3480    COM /Index_real/ Buff_freq(*),Buff_gain(*),Buff_offset(*),Buff_time(*)
3482    COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
3484    COM /Index_defaults/ Sample_freq,Events(*)
3486    !---------------------------------------------------------------------
```

```
3488    MAT Buff_id$= ("$")
3490    MAT No_buffers= (0)
3492    !
3494    Load_header                                   !Load index of data set
3496  SUBEND
3498  !________________________________________________________________________
3500 Deflection:SUB Deflection(OPTIONAL Id$)
3502  !
3504  ! Integrates an accelerometer signal twice with respect to time to
3506  ! produce a deflection signal. The offset is assumed to be zero.
3508  !========================================================================
3510    OPTION BASE 1
3512    COM /Index_string/ Buff_id$(*),Buff_title$(*),Buff_units$(*)
3514    COM /Accumulators/ No_acc,Acc_size,Acc1(*),Acc2(*),Acc3(*),Acc4(*),Acc5(
3516    COM /Raw_defaults/ INTEGER No_avg,Skip,REAL Start_time,Stop_time
3518    COM /Buff_defaults/ Buff_ingain
3520    !----------------------------------------------------------------------
3522    ALLOCATE Title$[30]
3524    INTEGER Flag
3526    !
3528    IF NPAR=0 OR Id$="" THEN
3530      Ask_for_channel(1,"Enter accelerometer designation (e.g. ACV201)",Id$,
3532      IF Flag<>1 THEN
3534        PRINT Id$;" not found"
3536        SUBEXIT
3538      END IF
3540    END IF
3542    Row=0
3544    Raw_to_acc(Row,Id$,1,No_avg,Skip,Start_time,Stop_time)
3546    Delta_t=MAX(No_avg,Skip)/FNSample_freq(Row,1)
3548    Acc_int_1t(Delta_t)
3550    MAT Acc1= Acc2
3552    Acc_int_1t(Delta_t)
3554    !-----------------------------!
3556    ! Convert meters to mm
3558    !-----------------------------!
3560    MAT Acc2= (1000)*Acc2
3562    New_id$="DEF"&Id$[4,6]
3564    Title$="Vertical Acceleration"
3566    Acc_to_buff(2,New_id$,Title$,"mm",Buff_ingain,0)
3568    !
3570    DEALLOCATE Title$
3572  SUBEND
3574  !________________________________________________________________________
3576 Delete_buffer:SUB Delete_buffer(Del_id$)
3578  !
3580  ! Deletes one data buffer from the index, and purges the file.
3582  !========================================================================
3584    OPTION BASE 1
3586    COM /Index_string/ Buff_id$(*),Buff_title$(*),Buff_units$(*)
3588    COM /Index_real/ Buff_freq(*),Buff_gain(*),Buff_offset(*),Buff_time(*)
3590    COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
3592    COM /Msus/ Msus_raw1$,Msus_raw2$,Msus_buff$,Msus_ext$,Test_hdr$
3594    !----------------------------------------------------------------------
3596    INTEGER I
3598    !
3600    Check_index(2,Del_id$,Flag)
3602    !
3604    IF Flag<>0 THEN .                             !Decrement index entries
3606      DISP "Deleting buffer ";Del_id$
```

```
3608      FOR I=Flag TO No_buffers(2)-1
3610        Buff_id$(I,2)=Buff_id$(I+1,2)
3612        Buff_title$(I,2)=Buff_title$(I+1,2)
3614        Buff_units$(I,2)=Buff_units$(I+1,2)
3616        Buff_freq(I,2)=Buff_freq(I+1,2)
3618        Buff_gain(I,2)=Buff_gain(I+1,2)
3620        Buff_offset(I,2)=Buff_offset(I+1,2)
3622        Buff_points(I,2)=Buff_points(I+1,2)
3624        Buff_start(I,2)=Buff_start(I+1,2)
3626        Buff_event(I,2)=Buff_event(I+1,2)
3628        Buff_end(I,2)=Buff_end(I+1,2)
3630      NEXT I
3632      No_buffers(2)=No_buffers(2)-1
3634      ON ERROR GOTO Err_file_purge
3636      PURGE Test_hdr$&Del_id$&Meus_buff$
3638      OFF ERROR
3640      DISP
3642    ELSE
3644      PRINT "Buffer ";Del_id$;" not found to delete!"
3646    END IF
3648    SUBEXIT
3650    !++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
3652 Err_file_purge:                                                  !
3654    PRINT ERRM$
3656    PAUSE
3658  SUBEND
3660  !______________________________________________________________________________
3662  SUB Dump_channel(Row,Id$)
3664 Dump_channel: !
3666    !----------------------------!
3668    ! This prints the selected portion of a raw or buffer data channel
3670    ! in engineering units on the current printer.
3672    !----------------------------!
3674    OPTION BASE 1
3676    COM /Raw_defaults/ INTEGER No_avg,Skip,REAL Start_time,Stop_time
3678    COM /Accumulators/ No_acc,Acc_size,Acc1(*),Acc2(*),Acc3(*),Acc4(*),Acc5(
3680    COM /Hardware/ Prt_address,Current_prt,Computer$
3682    INTEGER Flag
3684    !----------------------------!
3686    ! Load data
3688    !----------------------------!
3690    Flag=0
3692    Exec_module(Id$,Flag,Row)
3694    SELECT Flag
3696    CASE 0,2
3698      Buff_to_acc(Row,Id$,1)
3700    CASE 1
3702      Raw_to_acc(Row,Id$,1,No_avg,Skip,Start_time,Stop_time)
3704    CASE ELSE
3706      PRINT Id$;" not found to print"
3708      SUBEXIT
3710    END SELECT
3712    ALLOCATE Temp(FNSize_acc)
3714    Mindata=1
3716    Maxdata=SIZE(Acc1,1)
3718    PRINT
3720    PRINT TABXY(0,20);"Size of data is ";Maxdata;" samples"
3722    !----------------------------!
3724    ! Prompt user for subset of data available.
3726    !----------------------------!
```

```
3728    REPEAT
3730      BEEP
3732      INPUT "Enter starting and ending sample no.",Mindata,Maxdata
3734    UNTIL Mindata>0 AND Maxdata<=SIZE(Acc1,1)
3736    ASSIGN @Prt TO Current_prt
3738    Rows=(1+Maxdata-Mindata) DIV 6
3740    FOR I=Mindata TO (Mindata-1)+Rows*6 STEP 6
3742      PRINT USING Outimage;I;Acc1(I);Acc1(I+1),Acc1(I+2),Acc1(I+3),Acc1(I+4)
3744    NEXT I
3746    Leftovers=(1+Maxdata-Mindata) MOD 6
3748    IF Leftovers>0 THEN
3750      PRINT USING "#,DDDDD,""! """;Mindata+Rows*6
3752      FOR I=Mindata+Rows*6 TO (Mindata-1)+Rows*6+Leftovers
3754        PRINT USING "#,MD.DDE,2X";Acc1(I)
3756      NEXT I
3758    END IF
3760 Outimage:IMAGE DDDDD,"! ",6(MD.DDE,2X)
3762  SUBEND
3764  !_______________________________________________________________________
3766 Dump_index:SUB Dump_index
3768  !
3770  ! This dumps the complete contents of the raw and buffer file index
3772  ! onto the current printer. It is done in 2 sections so they can be
3774  ! pasted together.
3776  !=======================================================================
3778    OPTION BASE 1
3780    COM /Index_string/ Buff_id$(*),Buff_title$(*),Buff_units$(*)
3782    COM /Index_real/ Buff_freq(*),Buff_gain(*),Buff_offset(*),Buff_time(*)
3784    COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
3786    COM /Hardware/ Prt_address,Current_prt,Computer$
3788    !-----------------------------------------------------------------------
3790    ASSIGN @Out TO Current_prt
3792    OUTPUT @Out USING Image1;"Id$";"Title$";"Units$"
3794    OUTPUT @Out;"Freq    ";"Gain    ";"  Offset"
3796    OUTPUT @Out;"----------------------------------------------------------
3798    FOR Ind=1 TO 2
3800      FOR Buff=1 TO No_buffers(Ind)
3802        OUTPUT @Out USING Image1;Buff_id$(Buff,Ind);Buff_title$(Buff,Ind);Bu
3804        OUTPUT @Out USING Image2;Buff_freq(Buff,Ind);Buff_gain(Buff,Ind);Buf
3806      NEXT Buff
3808    NEXT Ind
3810 Image1:IMAGE  #,8A,20A,2X,10A,2X
3812 Image2:IMAGE  DDDD.D,X,D.DESZZ,X,SD.DESZZ
3814 Image3:IMAGE  8A,4(SD.DESZZ,X),DDDD.DDD
3816    IF Current_prt=CRT THEN
3818      INPUT "Press RETURN to continue.",Ans$
3820    END IF
3822    IF Current_prt=Prt_address THEN OUTPUT Current_prt;"
```

```
                                                                        ";
3824    OUTPUT @Out;" Id$     ";" Points  ";" Start   ";" Event   ';' End      ';'
3826    OUTPUT @Out;"-----------------------------------------------------"
3828    FOR Ind=1 TO 2
3830      FOR Buff=1 TO No_buffers(Ind)
3832        OUTPUT @Out USING Image3;Buff_id$(Buff,Ind);Buff_points(Buff,Ind);Bu
3834      NEXT Buff
3836    NEXT Ind
3838  SUBEND
3840  !______________________________________________________________________
3842 Exec_module:SUB Exec_module(Module$,INTEGER Flag,REAL Row)
3844  !
3846  ! This executes a "calculation module" according to Module$.
3848  ! If Module$ matches a Raw or Buff file, then that is enough.
3850  ! The Buff files are checked first, then the raw files, and last
3852  ! the calculation modules.
3854  !
3856  ! INPUTS:
3858  !     Module$ - name of raw file, buffer, or calc module.
3860  !
3862  ! OUTPUTS:
3864  !     Flag    - status of search:
3866  !                    -1 = no module  found.
3868  !                     0 = Calculation module found (1 buffer file created
3870  !                         with same name as calc module).
3872  !                     1 = Raw file found.
3874  !                     2 = Buff file found.
3876  !                     3 = Calculation module found
3878  !                         (more than 1 buffer file created).
3880  !     Row      - Row of index where raw or buff file was found.
3882  !
3884  !CALLS:
3886  !     Calc_modules
3888  !     Check_index
3890  !======================================================================
3892    OPTION BASE 1
3894    DIM Dummy$[40]
3896    !
3898    Module$=UPC$(Module$)
3900    Flag=0
3902    Row=0
3904    !
3906    Check_index(2,Module$,Row)                          !Check if Buff exists
3908    IF Row>0 THEN
3910      Flag=2
3912    ELSE                                                !If not, try Raw
3914      Check_index(1,Module$,Row)
3916      IF Row>0 THEN
3918        Flag=1
3920      ELSE                                              !Must be a Calc module...
3922        Exec_flag=1
3924        Dummy$=""
3926        Calc_modules(Module$,Exec_flag,Dummy$)
3928        Flag=Exec_flag
3930      END IF
3932    END IF
3934  SUBEND
3936  !______________________________________________________________________
3938  !
3940 Ext_to_buff:SUB Ext_to_buff(Ext_id$,Buffer_id$)
```

```
3942  !
3944  ! This reads a previously written external data file and
3946  ! enters the data into a buffer data file.
3948  ! See also Buff_to_ext .
3950  !=====================================================================
3952    OPTION BASE 1
3954    COM /Index_string/ Buff_id$(*),Buff_title$(*),Buff_units$(*)
3956    COM /Index_real/ Buff_freq(*),Buff_gain(*),Buff_offset(*),Buff_time(*)
3958    COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
3960    COM /Msus/ Msus_raw1$,Msus_raw2$,Msus_buff$,Msus_ext$,Test_hdr$
3962    COM /Buff_defaults/ Buff_ingain
3964    COM /Raw_defaults/ INTEGER No_avg,Skip,REAL Start_time,Stop_time
3966    !-------------------------------------------------------------------
3968    INTEGER Flag,Events(3)
3970    DIM Bufftitle$[30]
3972    ALLOCATE Buffdata(FNSize_acc)
3974    ALLOCATE INTEGER Intdata(FNSize_acc)
3976    !-----------------------------!
3978    Buffer_id$=UPC$(Buffer_id$)
3980    Ext_id$=UPC$(Ext_id$)
3982    !-----------------------------!
3984    Check_index(2,Buffer_id$,Row)
3986    IF Row<>0 THEN
3988      PRINT "Duplicate buffer name..Cannot transfer in external file"
3990      GOTO Endofit
3992    END IF
3994    Row=No_buffers(2)+1
3996    ON ERROR GOTO Err_file
3998    File_name$=Ext_id$&Msus_ext$
4000    ASSIGN @File TO File_name$
4002    ENTER @File;Buffid$
4004    ENTER @File;Bufftitle$
4006    ENTER @File;Buffunits$
4008    ENTER @File;Bufffreq
4010    ENTER @File;Gain
4012    ENTER @File;Offset
4014    ENTER @File;Bufftime
4016    ENTER @File;Sizedata
4018    ENTER @File;Event_pointer
4020    !-----------------------------!
4022    PRINT Buffid$
4024    PRINT Bufftitle$
4026    PRINT Buffunits$
4028    PRINT Bufffreq
4030    PRINT Gain
4032    PRINT Offset
4034    PRINT Bufftime
4036    PRINT Sizedata
4038    PRINT Event_pointer
4040    !-----------------------------!
4042    ! Read  data                  !
4044    !-----------------------------!
4046    REDIM Intdata(Sizedata)
4048    ENTER @File;Intdata(*)
4050    ASSIGN @File TO *
4052    OFF ERROR
4054    !-----------------------------!  Eng. units conversion
4056    MAT Buffdata= Intdata-(Offset)
4058    MAT Buffdata= Buffdata*(Gain)
4060    !-----------------------------!
```

```
4062    Events(1)=1
4064    Events(2)=INT(Event_pointer)
4066    Events(3)=Sizedata
4068    !---------------------------!
4070    Temp_to_buff(Buffdata(*),Buffer_id$,Bufftitle$,Buffunits$,Bufffreq,0,Eve
4072    GOTO Endofit
4074    !---------------------------!
4076 Err_file:   !
4078 Errfile:   !
4080    OFF ERROR
4082    PRINT ERRM$
4084    PRINT "Cannot find external file"
4086    GOTO Endofit
4088 Endofit:          !
4090    DEALLOCATE Intdata(*)
4092    DEALLOCATE Buffdata(*)
4094  SUBEND
4096  !______________________________________________________________________
4098 Atn: DEF FNAtn(Y,X)
4099  !
4102  ! Returns full arctan (-180 to 180)
4103  !======================================================================
4106    OPTION BASE 1
4107    !
4109    DEG
4110    Offset=90+-90*(X>0)
4112    IF X=0 THEN RETURN SGN(Y)*Offset
4114    IF Y=0 THEN RETURN 2*Offset
4116    RETURN SGN(Y)*(ABS(ATN(Y/X))+Offset)
4118  FNEND
4120  !______________________________________________________________________
4124 Buff_bytes:DEF FNBuff_bytes(@Buff)
4126  !
4128  ! Returns Current no. of bytes in an I/O path buffer.
4130  !======================================================================
4132    STATUS @Buff,4;Bytes
4134    RETURN Bytes
4136  FNEND
4138  !______________________________________________________________________
4142 Descriptor:DEF FNDescriptor$(Id$)
4144  !
4146  ! This matches the input Id$ to a descriptive value used for a plot title.
4148  ! DATA statements are used to hold the descriptive values.
4150  ! The match is found only to the no. of characters in the DATA statement;
4152  ! specific names (e.g. BD) should be placed before general (e.g. BD1).
4154  !======================================================================
4156    OPTION BASE 1
4158    !
4160 Titles:                                             !
4162    DIM Tx_id$[4],Tx_title$[30]
4164    DATA AD  ,"Actuator Displacement"
4166    DATA APR ,"Actuator Retract Pressure"
4168    DATA APE ,"Actuator Extend Pressure"
4170    DATA BD  ,"Blade Displacement"
4172    DATA BP  ,"Blade Surface Pressure"
4174    DATA BR  ,"Blade Rosette Strain"
4176    DATA BS  ,"Blade Single-Axis Strain"
4178    DATA FSG ,"Frame Girder Strain"
4180    DATA FSB.,"Frame Backstop Strain"
4182    DATA SPR ,"Spare"
```

```
4184    DATA RAMP,"Command"
4186    DATA END ,"Undefined"
4188    RESTORE Titles
4190    !
4192    LOOP
4194      READ Tx_id$,Tx_title$
4196      IF Tx_id$=Id$[2,LEN(Tx_id$)+1] THEN
4198        RETURN Tx_title$
4200      END IF
4202      IF Tx_id$="END" THEN
4204        PRINT "Undefined transducer type ";Id$;" in FNDescriptor"
4206        PAUSE
4208        RETURN Tx_title$
4210      END IF
4212    END LOOP
4214  FNEND
4216  !_____________________________________________________________________
4220 Event_time:DEF FNEvent_time(Row,INTEGER Index_no)
4222  !
4224  ! Calculate time of event for raw or buffer file
4226  !=====================================================================
4228    COM /Index_real/ Buff_freq(*),Buff_gain(*),Buff_offset(*),Buff_time(*)
4230    COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
4232    !-------------------------------------------------------------------
4234    RETURN Buff_event(Row,Index_no)/Buff_freq(Row,Index_no)
4236  FNEND
4238  !_____________________________________________________________________
4240  !
4242 File_size:DEF FNFile_size(@File)
4244  !
4246  ! Returns the no. of bytes to EOF
4248  !=====================================================================
4250    !
4252    STATUS @File,4;Rec_size
4254    STATUS @File,7;Rec
4256    STATUS @File,8;Byt
4258    RETURN (Rec-1)*Rec_size+Byt-1
4260  FNEND
4262  !_____________________________________________________________________
4264 No_acc:DEF FNNo_acc
4266  !
4268  ! Returns no. of accumulators available.
4270  !=====================================================================
4272    OPTION BASE 1
4274    COM /Accumulators/ No_acc,Size_acc,Acc1(*),Acc2(*),Acc3(*),Acc4(*),Acc5(
4276    !-------------------------------------------------------------------
4278    RETURN No_acc
4280  FNEND
4282  !___________________________________________________________________!__
4284  !
4286 Pointer:DEF FNPointer(@File)
4288  !
4290  ! Finds current pointer setting of a file, in bytes.
4292  !=====================================================================
4294    !
4296    STATUS @File,5;Rec
4298    STATUS @File,6;Byt
4300    RETURN (Rec-1)*256+Byt-1
4302  FNEND
4304  !_____________________________________________________________________
```

```
4306  !
4308 Sample_freq:DEF FNSample_freq(Row,INTEGER Index_no)
4310  !
4312  ! Returns sample freq of raw or buffer file.
4314  !=========================================================================
4316    COM /Index_real/ Buff_freq(*),Buff_gain(*),Buff_offset(*),Buff_time(*)
4318    !-----------------------------------------------------------------------
4320    RETURN Buff_freq(Row,Index_no)
4322  FNEND
4324  !_________________________________________________________________________
4326  !
4328 Size_acc:DEF FNSize_acc
4330  !
4332  ! Returns max. available size of the accumulators.
4334  !=========================================================================
4336    OPTION BASE 1
4338    COM /Accumulators/ No_acc,Size_acc,Acc1(*),Acc2(*),Acc3(*),Acc4(*),Acc5(
4340    !-----------------------------------------------------------------------
4342    RETURN Size_acc
4344  FNEND
4346  !_________________________________________________________________________
4348  !
4350 Start_sample:DEF FNStart_sample(Start_time,Row,INTEGER Index)
4352  !
4354  ! Calculate start sample given start time.
4356  ! This is used by virtually all routines that access raw data files.
4358  !=========================================================================
4360    OPTION BASE 1
4362    COM /Index_real/ Buff_freq(*),Buff_gain(*),Buff_offset(*),Buff_time(*)
4364    COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
4366    !-----------------------------------------------------------------------
4368    Start_sample=Buff_start(Row,Index)+INT(Start_time*Buff_freq(Row,Index))
4370    IF Start_sample<1 THEN
4372      PRINT "Start time (";Start_time;" seconds) not chosen correctly for th
4374    END IF
4376    RETURN Start_sample
4378  FNEND
4380  !_________________________________________________________________________
4382  !
4384 Start_time:DEF FNStart_time(Row,INTEGER Index_no)
4386  !
4388  ! Calculate "raw" time of sample selected to be t=0
4390  !=========================================================================
4392    COM /Index_real/ Buff_freq(*),Buff_gain(*),Buff_offset(*),Buff_time(*)
4394    COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
4396    !-----------------------------------------------------------------------
4398    RETURN Buff_start(Row,Index_no)/Buff_freq(Row,Index_no)
4400  FNEND
4402  !_________________________________________________________________________
4404  !
4406 Stop_sample:DEF FNStop_sample(Stop_time,Row,INTEGER Index)
4408  !
4410  ! Calculate stop sample given stop time.
4412  ! This is used by virtually all routines that access raw data files.
4414  !=========================================================================
4416    OPTION BASE 1
4418    COM /Index_real/ Buff_freq(*),Buff_gain(*),Buff_offset(*),Buff_time(*)
4420    COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
4422    !-----------------------------------------------------------------------
4424    !
```

```
4426     Stop_sample=Buff_start(Row,Index)+INT(Stop_time*Buff_freq(Row,Index
4428     IF Stop_sample>Buff_points(Row,Index) OR Stop_time<0 THEN
4430       PRINT "Stop_time (";Stop_time;" seconds) not chosen correctly for this
4432       PRINT "Loading data to end of file."
4434       RETURN Buff_points(Row,Index)
4436     ELSE
4438       RETURN Stop_sample
4440     END IF
4442   FNEND
4444   !_______________________________________________________________________
4446 Get_stats:SUB Get_stats(Row,Id$,Index_no,Data_min,Data_mean,Data_max)
4448   !
4450   ! This calculates the basic statistics of a raw or buffer data file.
4452   ! Input variables are the usual ones to access raw data files, except
4454   ! that the Raw_defaults COM block is used to access the values for
4456   ! the chosen time window and the averaging or decimation factor
4458   ! (other routines such as Plot_raw require these variables in the
4460   ! CALL ).
4462   !=======================================================================
4464     OPTION BASE 1
4466     COM /Index_real/ Buff_freq(*),Buff_gain(*),Buff_offset(*),Buff_time(*)
4468     COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
4470     COM /Raw_defaults/ INTEGER No_avg,Skip,REAL Start_time,Stop_time
4472     !---------------------------------------------------------------------
4474     Id$=UPC$(Id$)
4476     IF Row=0 THEN
4478       Check_index(Index_no,Id$,Row)
4480       IF Row=0 THEN
4482         Row=-1
4484         PRINT Id$;" not found for statistics"
4486         SUBEXIT
4488       END IF
4490     END IF
4492     !----------------------------!
4494     ! Stats of a RAW file        !
4496     !----------------------------!
4498     IF Index_no=1 THEN
4500       Datasize=Buff_points(Row,1)
4502       Start_sample=INT(Buff_start(Row,1)+Start_time*Buff_freq(Row,1))
4504       IF Stop_time>0 THEN
4506         Stop_sample=INT(Buff_start(Row,1)+Stop_time*Buff_freq(Row,1))
4508       ELSE
4510         Stop_sample=Datasize
4512       END IF
4514       Samples=Stop_sample-Start_sample+1
4516       IF Samples>32767 THEN
4518         PRINT "Start and Stop times too wide to perform statistics without a
4520         SUBEXIT
4522       END IF
4524       ALLOCATE Tempdata(Samples),INTEGER Intdata(Samples)
4526       Raw_to_int(Row,Id$,Intdata(*),1,1,Start_sample,Stop_sample)
4528       IF Row<>-1 THEN
4530         Data_min=Buff_gain(Row,1)*MIN(Intdata(*))+Buff_offset(Row,1)
4532         Data_max=Buff_gain(Row,1)*MAX(Intdata(*))+Buff_offset(Row,1)
4534         MAT Tempdata= Intdata
4536         Data_mean=(Buff_gain(Row,1)*SUM(Tempdata)/SIZE(Tempdata,1))+Buff_off
4538       END IF
4540       !----------------------------!
4542       ! Stats of a BUFF file       !
4544       !----------------------------!
```

```
4546    ELSE
4548      ALLOCATE Tempdata(FNSize_acc)
4550      Buff_to_temp(Row,Id$,Tempdata(*))
4552      IF Row<>-1 THEN
4554        Data_min=MIN(Tempdata(*))
4556        Data_max=MAX(Tempdata(*))
4558        Data_mean=SUM(Tempdata)/SIZE(Tempdata,1)
4560      END IF
4562    END IF
4564  SUBEND
4566  !________________________________________________________________________!
4568  SUB Keys_off
4570 Keys_off: !
4572  !----------------------------!
4574  ! Turn off softkeys          !
4576  !----------------------------!
4578    STATUS 1,12;S
4580    IF S<>1 THEN
4582      OUTPUT KBD;"!";
4584    END IF
4586  SUBEND
4588  !________________________________________________________________________!
4590  SUB Keys_on
4592 Keys_on: !
4594  !----------------------------!
4596  ! Turn on softkeys           !
4598  !----------------------------!
4600    ALPHA ON
4602    GRAPHICS OFF
4604    STATUS 1,12;S
4606    IF S=1 THEN
4608      OUTPUT KBD;"!";
4610    END IF
4612  SUBEND
4614  !________________________________________________________________________!
4616  SUB Knob_routine(Start_time,Stop_time)
4618 Knob_routine: !
4620    !----------------------------!
4622    ! This allows the user to set the start and end times of the chosen
4624    ! time window by moving a vertical line across the last plot.
4626    ! The line is moved either by the knob (9816) or by softkeys (310).
4628    !----------------------------!
4630    OPTION BASE 1
4632    COM /Accumulators/ No_acc,Acc_size,Acc1(*),Acc2(*),Acc3(*),Acc4(*),Acc5(
4634    COM /Graph_limits/ Viewxmin,Viewxmax,Viewymin,Viewymax,Xmin,Xmax,Ymin,Ym
4636    COM /Hardware/ Prt_address,Current_prt,Computer$
4638    REAL X_pos
4640    Old_start=Start_time
4642    Old_stop=Stop_time
4644    !----------------------------!
4646    Clear_screen
4648    OFF KEY
4650    ON KEY 0 LABEL "Start   time    ",4 GOSUB Set_start_time
4652    ON KEY 1 LABEL "Stop    time    ",4 GOSUB Set_stop_time
4654    ON KEY 2 LABEL "Restore last    ",4 GOSUB Restore_last
4656    ON KEY 3 LABEL "Exit            ",4 GOTO Exit
4658    ON KEY 4 LABEL "  ***           ",1 GOSUB Exit
4660    ON KEY 5 LABEL "  ***           ",1 GOSUB Exit
4662    ON KEY 6 LABEL "  ***           ",1 GOSUB Exit
4664    ON KEY 7 LABEL "  ***           ",1 GOSUB Exit
```

```
4666    ON KEY 8 LABEL "  ***              ",1 GOSUB Exit
4668    ON KEY 9 LABEL "  ***              ",1 GOSUB Exit
4670    !----------------------------!
4672    ! Define softkey cursor movement keys
4674    ! Series 300 only.
4676    !----------------------------!
4678    IF 1 THEN !Computer$<>"9816" THEN
4680      ON KEY 6 LABEL "<-----            ",4 GOSUB Move_far_left
4682      ON KEY 7 LABEL "  <-              ",4 GOSUB Move_left
4684      ON KEY 8 LABEL "  ->              ",4 GOSUB Move_right
4686      ON KEY 9 LABEL "----->            ",4 GOSUB Move_far_right
4688    END IF
4690    !----------------------------!
4692    GLOAD Screen(*)
4694    PEN 0
4696    X_pos=.1*Xmax
4698    Top=Ymax
4700    Bottom=Ymin
4702    PLOT X_pos,Bottom,-2
4704    PLOT X_pos,Top,-1
4706    ON KBD,3 RECOVER Exit
4708    ON KNOB .05,2 GOSUB Move_line
4710 Loop: !
4712    PRINT TABXY(1,1);"Start time=";Start_time;"sec          "
4714    PRINT TABXY(1,2);"Stop time =";Stop_time;"sec          "
4716    GOTO Loop
4718    !----------------------------!
4720    ! Knob movement subroutine    !
4722    !----------------------------!
4724 Move_line: !
4726    PLOT X_pos,Top,-2
4728    PLOT X_pos,Bottom,-1
4730    X_pos=X_pos+KNOBX*(Xmax-Xmin)/Acc_size*(INT(Acc_size/1000))
4732    X_pos=X_pos+KNOBY*(Xmax-Xmin)/(Acc_size/5)*(INT(Acc_size/1000))
4734    IF X_pos>=Xmax THEN X_pos=Xmin+(Xmax-Xmin)/Acc_size
4736    IF X_pos<=Xmin THEN X_pos=Xmax
4738    PLOT X_pos,Top,-2
4740    PLOT X_pos,Bottom,-1
4742    PRINT TABXY(40,1);"Time=";(INT(X_pos*1000))/1000;"sec          "
4744    RETURN
4746    !----------------------------!
4748    ! Softkey move subroutines    !
4750    !----------------------------!
4752 Move_left: !
4754    PLOT X_pos,Top,-2
4756    PLOT X_pos,Bottom,-1
4758    X_pos=X_pos-(Xmax-Xmin)/Acc_size*(INT(Acc_size/1000))
4760    IF X_pos<=Xmin THEN X_pos=Xmax
4762    PLOT X_pos,Top,-2
4764    PLOT X_pos,Bottom,-1
4766    GOTO End_move
4768    !----------------------------!
4770 Move_right: !
4772    PLOT X_pos,Top,-2
4774    PLOT X_pos,Bottom,-1
4776    X_pos=X_pos+(Xmax-Xmin)/Acc_size*(INT(Acc_size/1000))
4778    IF X_pos>=Xmax THEN X_pos=Xmin
4780    PLOT X_pos,Top,-2
4782    PLOT X_pos,Bottom,-1
4784    GOTO End_move
```

```
4786     !-----------------------------!
4788 Move_far_left:!
4790     PLOT X_pos,Top,-2
4792     PLOT X_pos,Bottom,-1
4794     X_pos=X_pos-10*(Xmax-Xmin)/Acc_size*(INT(Acc_size/1000))
4796     IF X_pos<=Xmin THEN X_pos=Xmax
4798     PLOT X_pos,Top,-2
4800     PLOT X_pos,Bottom,-1
4802     GOTO End_move
4804     !-----------------------------!
4806 Move_far_right: !
4808     PLOT X_pos,Top,-2
4810     PLOT X_pos,Bottom,-1
4812     X_pos=X_pos+10*(Xmax-Xmin)/Acc_size*(INT(Acc_size/1000))
4814     IF X_pos>=Xmax THEN X_pos=Xmin
4816     PLOT X_pos,Top,-2
4818     PLOT X_pos,Bottom,-1
4820     GOTO End_move
4822     !-----------------------------!
4824 End_move: !
4826     PRINT TABXY(40,1);"Time=";(INT(X_pos*1000))/1000;"sec       "
4828     RETURN
4830     !-----------------------------!
4832     ! Other subroutines
4834     !-----------------------------!
4836 Set_start_time: !
4838     Start_time=(INT(X_pos*1000))/1000
4840     RETURN
4842     !-----------------------------!
4844 Set_stop_time: !
4846     Stop_time=(INT(X_pos*1000))/1000
4848     RETURN
4850     !-----------------------------!
4852 Restore_last: !
4854     Start_time=Old_start
4856     Stop_time=Old_stop
4858     RETURN
4860     !-----------------------------!
4862 Exit: !
4864     OFF KBD
4866     OFF KNOB
4868   SUBEND
4870   !______________________________________________________________________
4872 List_calcs:SUB List_calcs
4874   !
4876   ! Print the calculation modules available and their associated
4878   ! descriptions.
4880   !
4882   ! Calls: Calc_modules
4884   !=====================================================================
4886     OPTION BASE 1
4888     COM /Calc_modules/ Module_index$(*),First_calc,No_calcs
4890     !-------------------------------------------------------------------
4892     ALLOCATE Calc_desc$[20]
4894     !
4896     ! Dummy read if index has not been initialized
4898     !
4900     IF First_calc=0 THEN
4902       Calc_modules("",0,Calc_desc$)
4904     END IF
```

```
4906     !
4908 Calc_index:IMAGE 10A,40A
4910      PRINT
4912      PRINT "CALCULATION MODULES AVAILABLE"
4914      PRINT "--------------------------------------------------------"
4916      FOR I=1 TO No_calcs
4918        PRINT USING Calc_index;Module_index$(I,1),Module_index$(I,2)
4920      NEXT I
4922      PRINT "--------------------------------------------------------"
4924    SUBEND
4926    !_________________________________________________________________
4928 List_trans:SUB List_trans
4930    !
4932    ! Lists transducer info on the current printer
4934    !=================================================================
4936      OPTION BASE 1
4938      COM /Transducers/ Labels$(*),Mode$(*),Ad_gains(*),Gains(*)
4940      COM /Hardware/ Prt_address,Current_prt,Computer$
4942      !---------------------------------------------------------------
4944      Un$=CHR$(132)
4946      Nor$=CHR$(128)
4948      Clear_screen
4950      PRINT " ";Un$;"  Transducer List                    ";Nor$;"  ";Un$;"
4952      PRINT "|TXDCR |Serial| Dist. | Angle | Depth||TXDCR |Serial| Dist. | Ang
4954      PRINT "|";Un$;"  ID   |  No. |  (m)  | (Deg) |  (m) ";Nor$;"||";Un$;"  ID
4956      Lines=3
4958      FOR I=1 TO 4
4960        FOR J=1 TO 16 STEP 2
4962          IF Labels$(I,J,1)="" THEN GOTO There_too
4964          PRINT USING Trans_image;"|";Labels$(I,J,1);"|";Labels$(I,J,2);"|";Lo
4966          PRINT USING Trans_image2;"|";Labels$(I,J+1,1);"|";Labels$(I,J+1,2);"
4968          Lines=Lines+1
4970          PRINT
4972          IF J=16 THEN
4974            IF Lines<18 THEN
4976              GOTO There
4978            ELSE
4980              Lines=0
4982              PRINT CHR$(129);" Press Return ";CHR$(129)
4984              Wait_for_key
4986            END IF
4988          END IF
4990          IF Lines=18 AND Labels$(I,J+1,1)<>"" AND Current_prt=CRT THEN
4992            Lines=0
4994            PRINT CHR$(129);" Press Return ";CHR$(128)
4996            Wait_for_key
4998          END IF
5000 There: !
5002        NEXT J
5004      NEXT I
5006 There_too: !
5008 Trans_image:IMAGE $,1A,6A,1A,6A,1A,2X,DDD.D,1A,2X,DDD.D,1A,1X,DDD.D,1A
5010 Trans_image2:IMAGE $,1A,6A,1A,6A,1A,2X,DDD.D,1A,2X,DDD.D,1A,1X,DDD.D,1A
5012      PRINT "|";Un$;"      |      |       |       |      ";Nor$;"||";Un$;"
5014    SUBEND
5016    !______________________________________________________________!
5018    SUB Load_config
5020 Load_config: !
5022      !------------------------------------------------------------!
5024      ! This allows recovery of the data files saved via the Save_config
```

```
5026      ! subprogram (Ref.)
5029      !-----------------------------------------------------------------!
5030      OPTION BASE 1
5032      COM /Index_string/ Buff_id$(*),Buff_title$(*),Buff_units$(*)
5034      COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
5036      COM /Msus/ Msus_raw1$,Msus_raw2$,Msus_buff$,Msus_ext$,Test_hdr$
5038      ALLOCATE File_pre$[5],Buffer_id$(150)[7]
5040      !----------------------------!
5042      REPEAT
5044        INPUT "Enter name of configuration file -",File_config$
5046        IF LEN(File_config$)>10 THEN
5048          DISP "Filename too long - must be 10 characters or less."
5050          WAIT 1.5
5052        END IF
5054      UNTIL File_config$<>"" AND LEN(File_config$)<11
5056      !----------------------------!
5058      DISP "Loading configuration file ";File_config$;" from ";Msus_ext$;"."
5060      ON ERROR GOTO No_file_found
5062      ASSIGN @Config TO File_config$&Msus_ext$
5064      OFF ERROR
5066      ENTER @Config;File_pre$
5068      ON END @Config GOTO End_of_file
5070      FOR I=1 TO 150
5072        ENTER @Config;Buffer_id$(I)
5074      NEXT I
5076      !----------------------------!
5078      DISP "What!! I've reached 150 buffers!"
5080      PAUSE
5082      SUBEXIT
5084 End_of_file:   !
5086      ASSIGN @Config TO *
5088      FOR Count=1 TO I-1
5090        Ext_to_buff(File_pre$&Buffer_id$(Count),Buffer_id$(Count))
5092      NEXT Count
5094      DISP "Done."
5096      SUBEXIT
5098 No_file_found:   !
5100      PRINT "Configuration file ";File_config$;" not found"
5102   SUBEND
5104    !__________________________________________________________________
5106    !
5108 Load_header:SUB Load_header
5110    !
5112    !  Reads test header file from data disk. Also
5114    !  builds index for raw files.
5116    !  The function FNDescriptor is used to supply descriptions of the
5118    !  various data channels.
5120    !==================================================================
5122      OPTION BASE 1
5124      COM /Index_string/ Buff_id$(*),Buff_title$(*),Buff_units$(*)
5126      COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
5128      COM /Index_real/ Buff_freq(*),Buff_gain(*),Buff_offset(*),Buff_time(*)
5130      COM /Index_defaults/ Sample_freq,Events(*)
5132      COM /Raw_defaults/ INTEGER No_avg,Skip,REAL Start_time,Stop_time
5134      COM /Msus/ Msus_raw1$,Msus_raw2$,Msus_buff$,Msus_ext$,Test_hdr$
5136      COM /Transducers/ Labels$(*),Mode$(*),Ad_gains(*),Gains(*)
5138      COM /Hardware/ Prt_address,Current_prt,Computer$
5140      !-----------------------------------------------------------------
5142      DIM Test_name$[20],Test_desc$[20],Shunt(20)
5144      INTEGER I,J,No_cards,No_channels,Max_cards,Max_channels,No_windows,W
```

```
5146    !
5148 Load_disk:                                     !
5150    Request_test(Stat)
5152    IF Stat<>1 THEN
5154      INPUT "Load the data disk, PUH-LEASE.",Ans$
5156      GOTO Load_disk
5158    END IF
5160    !
5162    PRINT "Loading test header file ";CHR$(129);Test_hdr$;CHR$(128)
5164    !
5166 Read_hdr_file:                                 !
5168    ON ERROR GOTO Nodisk
5170    ASSIGN @File TO Test_hdr$&Msus_raw1$
5172    OFF ERROR
5174    ENTER @File;No_windows,No_cards,No_channels,Max_cards,Max_channels
5176    ALLOCATE Duration(No_windows),Sample_rate(No_windows)
5178    ALLOCATE Samples(No_windows)
5180    REDIM Labels$(No_cards,No_channels/No_cards,SIZE(Labels$,3))
5182    REDIM Mode$(No_cards,No_channels/No_cards)
5184    REDIM Ad_gains(No_cards,No_channels/No_cards,SIZE(Ad_gains,3))
5186    REDIM Gains(No_cards,No_channels/No_cards,SIZE(Gains,3))
5188    ENTER @File;Duration(*)
5190    ENTER @File;Sample_rate(*)
5192    ENTER @File;Labels$(*)
5194    ENTER @File;Mode$(*)
5196    ENTER @File;Ad_gains(*)
5198    ENTER @File;Gains(*)
5200    ASSIGN @File TO *
5202    !
5204    No_buffers(1)=No_channels*No_windows
5206    MAT Samples= Duration . Sample_rate
5208    Z=0
5210    FOR Window=1 TO No_windows
5212      IF Window=1 THEN
5214        Start=0
5216      ELSE
5218        Start=Duration(Window-1)                    !Use to set Buff_time(*)
5220      END IF
5222      W=Window
5224      FOR I=1 TO No_cards
5226        FOR J=1 TO No_channels/No_cards
5228          Z=Z+1
5230          Buff_id$(Z,W)=VAL$(W)&Labels$(I,J,W)
5232          Buff_title$(Z,W)=FNDescriptor$(Buff_id$(Z,W))
5234          Buff_units$(Z,W)=Labels$(I,J,3)
5236          Buff_freq(Z,W)=Sample_rate(W)
5238          Buff_gain(Z,W)=Gains(I,J,2)*Gains(I,J,1)        ! eng./lsb
5240          Buff_offset(Z,W)=Gains(I,J,3)/Gains(I,J,1)      ! lsb
5242          Buff_points(Z,W)=Samples(W)
5244          Buff_time(Z,W)=Start
5246          Buff_start(Z,W)=1-Start*Sample_rate(W)          ! default
5248          Buff_event(Z,W)=-999                            ! default
5250          Buff_end(Z,W)=Samples(W)                        ! default
5252        NEXT J
5254      NEXT I
5256    NEXT Window
5258    !*
5260    !* Set values for default COM block
5262    !*
5264    IF Skip<>0 THEN
```

```
5266       Sample_freq=Sample_rate(1)/Skip
5268     ELSE
5270       IF No_avg<>0 THEN
5272         Sample_freq=Sample_rate(1)/No_avg
5274       ELSE
5276         Sample_freq=Sample_rate(1)
5278       END IF
5280     END IF
5282     !
5284     Start_time=0
5286     Stop_time=Duration(1)
5288     !
5290     Events(1)=1                                         ! Start of valid data
5292     Events(2)=-999                                      ! 'Event' undefined
5294     Events(3)=Samples(1)                                ! End of valid data
5296     !
5298     DISP "Raw file header loaded"
5300     SUBEXIT
5302     !++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
5304 Nodisk:                                                 !
5306     DISP "I can't seem to find the index file on this disk."
5308     BEEP
5310     WAIT .1
5312     BEEP
5314     WAIT .5
5316     GOTO Load_disk
5318   SUBEND
5320   !_______________________________________________________________________
5322 Matatn:SUB Matatn(Y(*),X(*),Angle(*))
5324   !
5326   ! Returns the arctan of two vectors (as another vector).
5328   !=======================================================================
5330     OPTION BASE 1
5332     INTEGER I
5334     !
5335     DEG
5337     Vecsize=MIN(SIZE(Y,1),SIZE(X,1))
5338     REDIM Angle(Vecsize)
5341     FOR I=1 TO Vecsize
5342       Offset=90+-90*(X(I)>0)
5344       IF X(I)=0 THEN
5346         Angle(I)=SGN(Y(I))*Offset
5348       ELSE
5350         IF Y(I)=0 THEN
5352           Angle(I)=2*Offset
5354         ELSE
5356           Angle(I)=SGN(Y(I))*(ABS(ATN(Y(I)/X(I)))+Offset)
5358         END IF
5360       END IF
5362     NEXT I
5364   SUBEND
5366   !_______________________________________________________________________
5368 Matsqr:SUB Matsqr(Vec(*))
5370   !
5372   ! Takes the square root of each element of a vector.
5374   ! Negative numbers give 0.
5376   !=======================================================================
5378     OPTION BASE 1
5380     INTEGER I
5382     !
```

```
5384    ON ERROR GOTO Fixit
5386    FOR I=1 TO SIZE(Vec,1)
5388      Vec(I)=SQR(Vec(I))
5390 Re_entry:NEXT I
5392    SUBEXIT
5394    !+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
5396 Fixit:Vec(I)=0
5398    GOTO Re_entry
5400  SUBEND
5402  !____________________________________________________________________
5404 Menus:SUB Menus
5406  !
5408  ! This is the master subprogram that allows the use of this program
5410  ! through a series of menus.
5412  ! Separate menus have been set up for the 9816 and the 310 computers
5414  ! because the softkey labels are slightly different.
5416  ! A menu selection causes execution of a subroutine, which, in general,
5418  ! will call the appropriate subprogram(s).
5420  !====================================================================
5422    OPTION BASE 1
5424    COM /Responses/ Response_id$,Ch_id$
5426    COM /Graph_limits/ Viewxmin,Viewxmax,Viewymin,Viewymax,Xmin,Xmax,Ymin,Ym
5428    COM /Graph_stuff/ Color(*),Line(*),Overlay_no,Full_screen,Split_format,A
5430    COM /Hardware/ Prt_address,Current_prt,Computer$
5432    COM /Raw_defaults/ INTEGER No_avg,Skip,REAL Start_time,Stop_time
5434    COM /Buff_defaults/ Buff_ingain
5436    COM /Transducers/ Labels$(*),Mode$(*),Ad_gains(*),Gains(*)
5438    COM /Msus/ Msus_raw1$,Msus_raw2$,Msus_buff$,Msus_ext$,Test_hdr$
5440    COM /Autosequence/ INTEGER Seq_no,Seq_flag,Sequence$(*)
5442    !------------------------------------------------------------------
5444    INTEGER Flag,Flag1,Flag2
5446    !
5448 Menu_9816:                                !
5450    SELECT Computer$
5452    CASE "9816"
5454    !
5456    !*** HP COMPUTER -- SERIES 200 MENUS ***
5458    !
5460 Menu1:                                    !Menu 1 -- MAIN MENU
5462 Main_menu:                                !
5464      OFF KEY
5466      ON KEY 0 LABEL "Set wdw (man) ",1 GOSUB Set_window
5468      ON KEY 1 LABEL "Set wdw (knb) ",1 GOSUB Knob_set
5470      ON KEY 2 LABEL " Load  window ",1 GOSUB Load_window
5472      ON KEY 3 LABEL " Auto   seq.  ",1 GOSUB Auto_sequence
5474      ON KEY 4 LABEL " Calc.  menu  ",1 GOTO Calc1
5476      ON KEY 5 LABEL " Util.  menu  ",1 GOTO Utilities
5478      ON KEY 6 LABEL " Plot   menu  ",1 GOTO Plot
5480      ON KEY 7 LABEL " I/O    menu  ",1 GOTO I_o
5482      ON KEY 8 LABEL "CREATE  ASCII ",1 GOSUB Cr_ascii
5484      ON KEY 9 LABEL " Exit  program",1 GOTO Exit_program
5486 Loop1:                                    !
5488      DISP "Menu 1: Setup"
5490      GOTO Loop1
5492      !
5494 Menu2:                                    !Menu 2 -- CALCULATIONS
5496 Calc1:                                    !
5498      OFF KEY
5500      ON KEY 0 LABEL " Calcs avail. ",1 GOSUB Calcs_avail
```

```
5502      ON KEY 1 LABEL "Execute calc. ",1 GOSUB Calculate
5504      ON KEY 2 LABEL " Stats (1 ch) ",1 GOSUB Stats_1ch
5506      ON KEY 3 LABEL " Stats (all)  ",1 GOSUB Stats_all
5508      ON KEY 4 LABEL "  ***         ",1 GOSUB Not_yet
5510      ON KEY 5 LABEL "  ***         ",1 GOSUB Not_yet
5512      ON KEY 6 LABEL "  ***         ",1 GOSUB Not_yet
5514      ON KEY 7 LABEL "  ***         ",1 GOSUB Not_yet
5516      ON KEY 8 LABEL " Chan. avail. ",1 GOSUB Ch_available
5518      ON KEY 9 LABEL " Main   menu  ",1 GOTO Main_menu
5520 Loop2:                                          !
5522      DISP "Menu 2: Calcs"
5524      GOTO Loop2
5526      !
5528 Menu3:                                          !Menu 3 -- UTILITIES
5530 Utilities:                                      !
5532      OFF KEY
5534      ON KEY 0 LABEL " Load  new tst",1 GOSUB Load_new_test
5536      ON KEY 1 LABEL " Clear buffers",1 GOSUB Clear_buffs
5538      ON KEY 2 LABEL "Delete buffer ",1 GOSUB Delete_buff
5540      ON KEY 3 LABEL "  ***         ",1 GOSUB Not_yet
5542      ON KEY 4 LABEL " Dump   index ",1 GOSUB Dump_index
5544      ON KEY 5 LABEL "  ***         ",1 GOSUB Not_yet
5546      ON KEY 6 LABEL " Load  config.",1 GOSUB Config_load
5548      ON KEY 7 LABEL " Save  config.",1 GOSUB Config_save
5550      ON KEY 8 LABEL " Chan. avail. ",1 GOSUB Ch_available
5552      ON KEY 9 LABEL " Main   menu  ",1 GOTO Main_menu
5554      !
5556 Loop3:                                          !
5558      DISP "Menu 3: Utilities"
5560      GOTO Loop3
5562 Menu4:                                          !Menu 4 -- PLOTTING
5564 Plot:                                           !
5566      OFF KEY
5568      ON KEY 0 LABEL " Plot  (full) ",1 GOSUB Plot_full
5570      ON KEY 1 LABEL "Plot xy(full) ",1 GOSUB Plot_full_xy
5572      ON KEY 2 LABEL " Plot  (split)",1 GOSUB Plot_split
5574      ON KEY 3 LABEL "Plot xy(split)",1 GOSUB Plot_split_xy
5576      ON KEY 4 LABEL " Plot  integer",1 GOSUB Plot_int
5578      ON KEY 5 LABEL "Overlay       ",1 GOSUB Plot_overlay
5580      ON KEY 6 LABEL "Replot  last  ",1 GOSUB Replot
5582      ON KEY 7 LABEL " Clear  plot  ",1 GOSUB Clear_plots
5584      ON KEY 8 LABEL "Change plotter",1 GOSUB Change_plotter
5586      ON KEY 9 LABEL " Main   menu  ",1 GOTO Main_menu
5588 Loop4:                                          !
5590      DISP "Menu 4: Plotting"
5592      GOTO Loop4
5594      !
5596 Menu5:                                          !Menu 5 -- I/O
5598 I_o: !
5600      OFF KEY
5602      ON KEY 0 LABEL "Create   ext  ",1 GOSUB Write_ext
5604      ON KEY 1 LABEL " Read    ext  ",1 GOSUB Read_ext
5606      ON KEY 2 LABEL " Write  stats ",1 GOSUB Stats_write
5608      ON KEY 3 LABEL " List   stats ",1 GOSUB Stats_read
5610      ON KEY 4 LABEL " Print channel",1 GOSUB Print_channel
5612      ON KEY 5 LABEL "  A/D  summary",1 GOSUB A_to_d_summ
5614      ON KEY 6 LABEL " Xdcr   list  ",1 GOSUB Trans_list
5616      ON KEY 7 LABEL "Change Printer",1 GOSUB Chg_printer
5618      ON KEY 8 LABEL " Chan. avail. ",1 GOSUB Ch_available
5620      ON KEY 9 LABEL " Main   menu  ",1 GOTO Main_menu
```

```
5622 Loop5:                                                       !
5624        DISP "Menu 5: Input/Output"
5626        GOTO Loop5
5628        !
5630    CASE "S300:10"
5632        !
5634        !*** HP COMPUTER -- SERIES 300 MENU ***
5636        !
5638 Menu1_300:                                                   !Menu 1 -- MAIN MENU
5640 Main_menu_300:                                               !
5642        OUTPUT KBD;"{";                                      !User keys on: series 300.
5644        CONTROL 2,15;1                                        !Kbd compatibility mode on
5646        OFF KEY
5648        ON KEY 0 LABEL "Set wdw (man) ",1 GOSUB Set_window
5650        ON KEY 1 LABEL "Set wdw (knb) ",1 GOSUB Knob_set
5652        ON KEY 2 LABEL " Load  window ",1 GOSUB Load_window
5654        ON KEY 3 LABEL " Auto   seq.  ",1 GOSUB Auto_sequence
5656        ON KEY 4 LABEL " Calc.  menu  ",1 GOTO Calc1_300
5658        ON KEY 5 LABEL "Utility menu  ",1 GOTO Utilities_300
5660        ON KEY 6 LABEL " Plot   menu  ",1 GOTO Plot_300
5662        ON KEY 7 LABEL "Input/ Output ",1 GOTO I_o_300
5664        ON KEY 8 LABEL "CREATE  ASCII ",1 GOSUB Cr_ascii
5666        ON KEY 9 LABEL " Exit  program",1 GOTO Exit_program
5668 Loope1:                                                      !
5670        DISP "Menu1: Main menu"
5672        GOTO Loope1
5674        !
5676 Menu2_300:                                                   !Menu 2 -- CALCULATIONS
5678 Calc1_300:                                                   !
5680        OFF KEY
5682        ON KEY 0 LABEL " Calc. avail. ",1 GOSUB Calcs_avail
5684        ON KEY 1 LABEL "Execute calc. ",1 GOSUB Calculate
5686        ON KEY 2 LABEL " Stats (1 ch) ",1 GOSUB Stats_1ch
5688        ON KEY 3 LABEL " Stats  (all) ",1 GOSUB Stats_all
5690        ON KEY 4 LABEL "  ***         ",1 GOSUB Not_yet
5692        ON KEY 5 LABEL "  ***         ",1 GOSUB Not_yet
5694        ON KEY 6 LABEL "  ***         ",1 GOSUB Not_yet
5696        ON KEY 7 LABEL "  ***         ",1 GOSUB Not_yet
5698        ON KEY 8 LABEL " Chan. avail. ",1 GOSUB Ch_available
5700        ON KEY 9 LABEL " Main   menu  ",1 GOTO Main_menu_300
5702 Loope2:                                                      !
5704        DISP "Menu 2: Calc menu"
5706        GOTO Loope2
5708 Menu3_300:                                                   !Menu 3 -- UTILITIES
5710 Utilities_300: !
5712        ON KEY 0 LABEL " Load  new tst",1 GOSUB Load_new_test
5714        ON KEY 1 LABEL " Clear buffers",1 GOSUB Clear_buffs
5716        ON KEY 2 LABEL "Delete buffer ",1 GOSUB Delete_buff
5718        ON KEY 3 LABEL "  ***         ",1 GOSUB Not_yet
5720        ON KEY 4 LABEL " Dump  index  ",1 GOSUB Dump_index
5722        ON KEY 5 LABEL "  ***         ",1 GOSUB Not_yet
5724        ON KEY 6 LABEL " Load  config.",1 GOSUB Config_load
5726        ON KEY 7 LABEL " Save  config.",1 GOSUB Config_save
5728        ON KEY 8 LABEL " Chan. avail. ",1 GOSUB Ch_available
5730        ON KEY 9 LABEL " Main   menu  ",1 GOTO Main_menu_300
5732 Loope3:                                                      !
5734        DISP "Menu 3: Utilities"
5736        GOTO Loope3
5738        !
5740 Menu4_300:                                                   !Menu 4 -- PLOTTING
```

```
5742 Plot_300:
5744       OFF KEY
5746       ON KEY 0 LABEL " Plot  (full) ",1 GOSUB Plot_full
5748       ON KEY 1 LABEL "Plot xy(full) ",1 GOSUB Plot_full_xy
5750       ON KEY 2 LABEL " Plot  (split)",1 GOSUB Plot_split
5752       ON KEY 3 LABEL "Plot xy(split)",1 GOSUB Plot_split_xy
5754       ON KEY 4 LABEL " Plot  integer",1 GOSUB Plot_int
5756       ON KEY 5 LABEL "Overlay       ",1 GOSUB Plot_overlay
5758       ON KEY 6 LABEL "Replot  last  ",1 GOSUB Replot
5760       ON KEY 7 LABEL " Clear  plot  ",1 GOSUB Clear_plots
5762       ON KEY 8 LABEL "Change plotter",1 GOSUB Change_plotter
5764       ON KEY 9 LABEL " Main   menu  ",1 GOTO Main_menu_300
5766 Loope4:                                                    !
5768       DISP "Menu 4: Plotting"
5770       GOTO Loope4
5772       !
5774 Menu5_300:                                                 !Menu 5 -- I/O
5776 I_o_300:                                                   !
5778       OFF KEY
5780       ON KEY 0 LABEL "Create   ext  ",1 GOSUB Write_ext
5782       ON KEY 1 LABEL " Read    ext  ",1 GOSUB Read_ext
5784       ON KEY 2 LABEL " Write  stats ",1 GOSUB Stats_write
5786       ON KEY 3 LABEL " List   stats ",1 GOSUB Stats_read
5788       ON KEY 4 LABEL " Print channel",1 GOSUB Print_channel
5790       ON KEY 5 LABEL "  A/D  summary",1 GOSUB A_to_d_summ
5792       ON KEY 6 LABEL " Xdcr   list  ",1 GOSUB Trans_list
5794       ON KEY 7 LABEL "Change printer",1 GOSUB Chg_printer
5796       ON KEY 8 LABEL " Chan. avail. ",1 GOSUB Ch_available
5798       ON KEY 9 LABEL " Main   menu  ",1 GOTO Main_menu_300
5800 Loope5:                                                    !
5802       DISP "Menu 5: Input/Output"
5804       GOTO Loope5
5806     CASE ELSE
5808       PRINT "ERROR in Menus: unknown computer type."
5810       PAUSE
5812     END SELECT
5814     SUBEXIT
5816     !++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
5818     !*** Menu driven Subroutines ***
5820     !
5822 Not_yet:                                                   !
5824     DISP "This function not implemented yet."
5826     WAIT 1
5828     RETURN
5830     !
5832 Set_window:                                                !
5834     No_avg=-1
5836     Skip=-1
5838     Start=Start_time
5840     Stop=Stop_time
5842     REPEAT
5844       INPUT "Enter start time in seconds",Start
5846     UNTIL Start>=0
5848     REPEAT
5850       INPUT "Enter end time in seconds",Stop
5852     UNTIL Stop>0 OR Stop=-1
5854     PRINT "Setting start and end times to ";Start,Stop
5856     Start_time=Start
5858     Stop_time=Stop
5860     RETURN
```

```
5862     !
5864 Knob_set:                                  !
5866     GRAPHICS ON
5868     IF Viewxmax=0 THEN
5870       DISP "There is no plot with which to set the window."
5872       WAIT 1.5
5874       RETURN
5876     END IF
5878     IF No_avg=-1 THEN Skip=0
5880     IF Skip=-1 THEN No_avg=0
5882     Knob_routine(Start_time,Stop_time)
5884     GRAPHICS OFF
5886     RETURN
5888     !
5890 Load_window:                               !
5892     DISP
5894     PRINT "What window?"
5896     RETURN
5898     !
5900 Auto_sequence:                             !
5902     Clear_screen
5904     Auto_seq(Sequence$(*))
5906     RETURN
5908     !
5910 Cr_ascii:                                  !
5912     Create_ascii
5914     RETURN
5916     !
5918 Read_ext:                                  !
5920     INPUT "Enter external file name",Ext_id$
5922     INPUT "Enter name for buffer",Buffer_id$
5924     Ext_to_buff(Ext_id$,Buffer_id$)
5926     RETURN
5928     !
5930 Write_ext:                                 !
5932     INPUT "Enter designator for source buffer file",Buffer_id$
5934     INPUT "Enter external file name",Ext_id$
5936     Buff_to_ext(Buffer_id$,Ext_id$)
5938     RETURN
5940     !
5942 Stats_write:                               !
5944     Clear_screen
5946     PRINT "Generating summary statistics file"
5948     REPEAT
5950       Ind=1
5952       INPUT "Enter 1 for raw files (default), 2 for buffers",Ind
5954     UNTIL Ind=1 OR Ind=2
5956     File$=Test_hdr$&"STATS"
5958     Write_stats(Ind,File$)
5960     RETURN
5962     !
5964 Stats_read:                                !
5966     File$=Test_hdr$&"STATS"
5968     Read_stats(File$)
5970     RETURN
5972     !
5974 Config_load:                               !
5976     Load_config
5978     RETURN
5980     !
```

```
5982 Config_save:                                    !
5984    Save_config
5986    RETURN
5988    !
5990 Calculate:                                      !
5992    Ask_for_channel(0,"Enter calculation module designator",Calc_id$,Flag,Ro
5994    IF Flag=-1 THEN
5996      PRINT "Calculation module";Calc_id$;" not found"
5998    END IF
6000    RETURN
6002    !
6004 Calcs_avail:                                    !
6006    List_calcs
6008    RETURN
6010    !
6012 Stats_1ch:                                      !
6014    Ask_for_channel(-1,"Enter channel designation",Ch_id$,Flag,Row)
6016    Flg=Flag
6018    SELECT Flg
6020    CASE 1,2
6022      Statistics(Row,Ch_id$,Flg)
6024    CASE 0
6026      Statistics(Row,Ch_id$,2)
6028    CASE ELSE
6030      PRINT "Channel ";Ch_id$;" not found."
6032    END SELECT
6034    RETURN
6036    !
6038 Stats_all:                                      !
6040    REPEAT
6042      INPUT "Enter 1 for raw files, 2 for buffer files.",Index_no
6044    UNTIL Index_no>0 AND Index_no<3
6046    Statistics(0,"ALL",Index_no)
6048    RETURN
6050    !
6052 Chg_printer:                                    !
6054    IF Current_prt=CRT THEN
6056      ON TIMEOUT 7,1 GOTO No_printer
6058      Current_prt=Prt_address
6060      OUTPUT Current_prt;"
6062      ON KEY 7 LABEL "Change printer ",1 GOSUB Chg_printer
6064      OFF TIMEOUT
6066      RETURN
6068    ELSE
6070      Current_prt=CRT
6072      ON KEY 7 LABEL "Change printer",1 GOSUB Chg_printer
6074      RETURN
6076    END IF
6078    !
6080 No_printer:                                     !
6082    OFF TIMEOUT
6084    PRINT "Cannot find printer at 701"
6086    Current_prt=CRT
6088    RETURN
6090    !
6092 Change_plotter:                                 !
6094    Chg_plotter("OTHER")
6096    RETURN
6098    !
6100 Load_new_test:                                  !
```

```
6102    Clear_index(1)
6104    Load_header
6106    RETURN
6108     !
6110 Clear_buffs:                                       !
6112    Clear_index(2)
6114    RETURN
6116     !
6118 Delete_buff:                                       !
6120    Buff_id$=""
6122    Ask_for_channel(0,"Enter buffer to be deleted",Buff_id$,Flag,Row)
6124    Delete_buffer(Buff_id$)
6126    RETURN
6128     !
6130 Print_channel:                                     !
6132    Ask_for_channel(-1,"Enter data channel to be printed",Id$,Flag,Row)
6134    Dump_channel(Row,Id$)
6136    RETURN
6138     !
6140 Trans_list:                                        !
6142    List_trans
6144    RETURN
6146     !
6148 A_to_d_summ:                                       !
6150    Ad_summary
6152    RETURN
6154     !
6156 Plot_int:                                          !
6158    Keys_off
6160    Plot_pos=0
6162    Ask_for_channel(1,"Enter raw data file to be plotted",Ch_id$,Flag,Row)
6164    Check_plotter
6166    Plot_int_raw(Plot_pos,Row,Ch_id$,No_avg,Skip,Start_time,Stop_time)
6168    Wait_for_key
6170    Keys_on
6172    RETURN
6174     !
6176 Plot_full:                                         !
6178    Keys_off
6180    Ask_for_channel(-1,"Enter channel designation",Ch_id$,Flag,Row)
6182    Plot_no=0
6184    Check_plotter
6186    GOSUB Plotgen_time
6188    Keys_on
6190    RETURN
6192     !
6194 Plot_split:                                        !
6196    Keys_off
6198    REPEAT
6200      INPUT "Update first or second plot?",Plot_no
6202    UNTIL Plot_no=1 OR Plot_no=2
6204    Ask_for_channel(-1,"Enter channel designation",Ch_id$,Flag,Row)
6206    Check_plotter
6208    GOSUB Plotgen_time
6210    Keys_on
6212    RETURN
6214     !
6216 Plot_overlay:                                      !
6218    Keys_off
6220    Ask_for_channel(-1,"Enter channel designation",Ch_id$,Flag,Row)
```

```
6222     SELECT Flag
6224     CASE 1
6226       Overlay_raw(Row,Ch_id$,No_avg,Skip,Start_time,Stop_time)
6228       Wait_for_key
6230     CASE 0,2
6232       Overlay_buff(Row,Ch_id$)
6234       Wait_for_key
6236     CASE ELSE
6238       PRINT "Nothing to plot."
6240     END SELECT
6242     Keys_on
6244     RETURN
6246     !
6248 Plot_full_xy:                                         !
6250     Keys_off
6252     Ask_for_channel(-1,"Enter channel designation for Y axis",Ch_id1$,Flag,R
6254     Ask_for_channel(-1,"Enter channel designation for X axis",Ch_id2$,Flag,R
6256     Plot_no=0
6258     Check_plotter
6260     GOSUB Plotgen_xy
6262     Keys_on
6264     RETURN
6266     !
6268 Plot_split_xy:                                        !
6270     GRAPHICS OFF
6272     Keys_off
6274     REPEAT
6276       INPUT "Update first or second plot?",Plot_no
6278     UNTIL Plot_no=1 OR Plot_no=2
6280     Ask_for_channel(-1,"Enter channel designation for Y axis",Ch_id1$,Flag,R
6282     Ask_for_channel(-1,"Enter channel designation for X axis",Ch_id2$,Flag,R
6284     Check_plotter
6286     GOSUB Plotgen_xy
6288     Keys_on
6290     RETURN
6292     !
6294 Clear_plots:                                          !
6296     Keys_off
6298     GCLEAR
6300     Plot_set(0)
6302     Keys_on
6304     RETURN
6306     !
6308 Replot:                                               !
6310     Keys_off
6312     GRAPHICS ON
6314     ALPHA OFF
6316     GLOAD Screen(*)
6318     Wait_for_key
6320     Keys_on
6322     RETURN
6324     !
6326 Dump_index:                                           !
6328     Dump_index
6330     RETURN
6332     !
6334 Ch_available:                                         !
6336     Clear_screen
6338     Print_index(1)
6340     Print_index(2)
```

```
6342   RETURN
6344   !
6346 Plotgen_xy:                                            !
6348   Errflag=0
6350   Exec_module(Ch_id1$,Flag1,Row1)
6352   SELECT Flag1
6354   CASE 1
6356     Raw_to_buff(Row1,Ch_id1$,Ch_id1$,No_avg,Skip,Start_time,Stop_time,Buff
6358   CASE 0,2
6360     !     (I'm all right, Jack.)
6362   CASE ELSE
6364     Errflag=1
6366   END SELECT                                             ! (Flag1)
6368   IF Errflag=0 THEN
6370     Exec_module(Ch_id2$,Flag2,Row2)
6372     SELECT Flag2
6374     CASE 1
6376       Raw_to_buff(Row2,Ch_id2$,Ch_id2$,No_avg,Skip,Start_time,Stop_time,Bu
6378     CASE 0,2
6380       ! (Good enough.)
6382     CASE ELSE
6384       Errflag=1
6386     END SELECT       ! (Flag2)
6388   END IF         !(Errflag)
6390   IF Errflag=0 AND Row1<>-1 AND Row2<>-1 THEN
6392     Plot_buff_1vs2(Plot_no,Row1,Ch_id1$,Row2,Ch_id2$,Errplot)
6394     IF Errplot=0 THEN GOSUB After_plot
6396   END IF
6398   RETURN
6400   !
6402 Plotgen_time:                                          !
6404   Exec_module(Ch_id$,Flag,Row)
6406   SELECT Flag
6408   CASE 1
6410     Plot_raw(Plot_no,Row,Ch_id$,No_avg,Skip,Start_time,Stop_time)
6412     IF Row<>-1 THEN
6414       GOSUB After_plot
6416     END IF
6418   CASE 0,2
6420     Plot_buff(Plot_no,Row,Ch_id$)
6422     IF Row<>-1 THEN
6424       GOSUB After_plot
6426     END IF
6428   CASE ELSE
6430     PRINT "Nothing to plot."
6432   END SELECT
6434   RETURN
6436   !
6438 After_plot:                                            !
6440   Wait_for_key
6442   RETURN
6444   !
6446 Exit_program:                                          !
6448   GRAPHICS OFF
6450   IF Computer$<>"9816" THEN
6452     CONTROL 2,12;0
6454   END IF
6456   DISP
6458   !
6460 End_menus:                                             !
```

```
6462  SUBEND
6464  !________________________________________________________________________
6466 Overlay_buff:SUB Overlay_buff(Row,Id$)
6468  !
6470  ! This is similar to Overlay_raw except it overlays a Buffer file
6472  ! on the existing plot (rather than a raw file).
6474  !========================================================================
6476    OPTION BASE 1
6478    COM /Index_string/ Buff_id$(*),Buff_title$(*),Buff_units$(*)
6480    COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
6482    COM /Index_real/ Buff_freq(*),Buff_gain(*),Buff_offset(*),Buff_time(*)
6484    COM /Graph_stuff/ Color(*),Line(*),Overlay_no,Full_screen,Split_format,A
6486    !----------------------------------------------------------------------
6488    Overlay_no=Overlay_no+1                         !Update color and pen type
6490    IF Overlay_no>SIZE(Color,1) THEN Overlay_no=1
6492    !
6494    ALLOCATE Tempdata(FNSize_acc)
6496                                          !
6498    Id$=UPC$(Id$)
6500    IF Id$="" THEN
6502      REPEAT
6504        BEEP
6506        INPUT "ID of Buffer to be plotted?",Id$
6508        Check_index(2,Id$,Row)
6510        IF Row=0 THEN
6512          BEEP
6514          DISP "Buffer not found"
6516          WAIT 1
6518        END IF
6520      UNTIL Row<>0
6522    ELSE
6524      IF Row=0 THEN
6526        Check_index(2,Id$,Row)
6528        IF Row=0 THEN
6530          PRINT "Cannot find buffer ";Id$;" in Plot_buff"
6532        END IF
6534      END IF
6536    END IF
6538    !
6540    Buff_to_temp(Row,Id$,Tempdata(*))               !Load data
6542                                          !
6544    GRAPHICS ON
6546    Start=Buff_time(Row,2)
6548    CALL Plot_time(Tempdata(*),1/Buff_freq(Row,2),Start,Color(Overlay_no),Li
6550    DEALLOCATE Tempdata(*)
6552    !
6554  SUBEND
6556  !________________________________________________________________________
6558  !
6560 Overlay_raw:SUB Overlay_raw(Row,Ch_id$,INTEGER No_avg,Skip,REAL Start_time,
6562  !
6564  ! Plots a raw data channel on top of the last plot. Scales, labels,
6566  ! etc. are used as is, so a certain amount of care should be used
6568  ! when utilizing this routine.
6570  ! Input parameters used are similar to those for Plot_raw.
6572  ! Pen color and line type are incremented through the values set up
6574  ! in the Color(*) and Line(*) arrays. A legend on the right of the
6576  ! plot is used to index the lines. The variable Overlay_no provides
6578  ! the index to distinguish between successive overlays.
6580  !========================================================================
6582   OPTION BASE 1
6584   COM /Index_string/ Buff_id$(*),Buff_title$(*),Buff_units$(*)
6586   COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
6588   COM /Index_real/ Buff_freq(*),Buff_gain(*),Buff_offset(*),Buff_time(*)
6590   COM /Graph_stuff/ Color(*),Line(*),Overlay_no,Full_screen,Split_format,A
6592   !------------------------------------------------------------------------
6594   DIM Lt_title$[40],Rt_title$[40],Xlbl$[20],Ylbl$[20]
6596   ALLOCATE Tempdata(FNSize_acc)
6598   !
6600   Overlay_no=Overlay_no+1             !Update pen and line type
6602   IF Overlay_no>SIZE(Color,1) THEN Overlay_no=1
6604   !
6606   Ch_id$=UPC$(Ch_id$)
6608   IF Ch_id$<>"" THEN
6610    IF Row=0 THEN
6612     Check_index(1,Ch_id$,Row)
6614     IF Row=0 THEN
6616      Row=-1
6618      PRINT Ch_id$;" not found in Plot_raw"
6620      SUBEXIT
6622     END IF
6624    END IF
6626   ELSE
6628    REPEAT
6630     BEEP
6632     INPUT "ID of Raw data file to be plotted?",Ch_id$
6634     Check_index(1,Ch_id$,Row)
6636     IF Row=0 THEN
6638      BEEP
6640      DISP "Raw data file not found"
6642      WAIT 1
6644     END IF
6646    UNTIL Row<>0
6648   END IF
6650   Time_offset=Start_time
6652   Start_sample=FNStart_sample(Start_time,Row,1)
6654   IF Start_sample<1 THEN
6656    Time_offset=Time_offset-(Start_sample-1)/Buff_freq(Row,1)
6658    Start_sample=1
6660   END IF
6662   Stop_sample=FNStop_sample(Stop_time,Row,1)
6664   Raw_to_temp(Row,Ch_id$,Tempdata(*),No_avg,Skip,Start_sample,Stop_sample)
6666   IF Skip=0 THEN
6668    Io_factor=No_avg
6670   ELSE
6672    Io_factor=Skip
6674   END IF
6676   !
6678   GRAPHICS ON
6680   Start=Buff_time(Row,2)
6682   CALL Plot_time(Tempdata(*),Io_factor/Buff_freq(Row,1),Time_offset,Color(
6684  SUBEND
6686  !_______________________________________________________________________
6688 Plot_buff:SUB Plot_buff(Plot_pos,Row,Id$)
6690  !
6692  ! This plots the data available in the given buffer.
6694  ! INPUTS:
6696  !       Plot_pos: position of plot:
6698  !                     0 = full screen
6700  !                     1 = top or left
```

```
6702  !                       2 = bottom or right
6704  !           Row: row of buffer in index, if known (0 if not).
6706  !                (also functions as a returned variable).
6708  !           Id$: Designation of data
6710  !======================================================================
6712    OPTION BASE 1
6714    COM /Index_string/ Buff_id$(*),Buff_title$(*),Buff_units$(*)
6716    COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
6718    COM /Index_real/ Buff_freq(*),Buff_gain(*),Buff_offset(*),Buff_time(*)
6720    COM /Graph_stuff/ Color(*),Line(*),Overlay_no,Full_screen,Split_format,A
6722    COM /Hardware/ Prt_address,Current_prt,Computer$
6724    COM /Msus/ Msus_raw1$,Msus_raw2$,Msus_buff$,Msus_ext$,Test_hdr$
6726    !---------------------------------------------------------------------
6728    DIM Lt_title$[40],Rt_title$[40],Xlbl$[20],Ylbl$[20]
6730    DIM Message1$[20],Message2$[20]
6732    ALLOCATE Tempdata(FNSize_acc)
6734    !
6736    Id$=UPC$(Id$)
6738    IF Id$="" THEN
6740      REPEAT
6742        BEEP
6744        INPUT "ID of Buffer to be plotted?",Id$
6746        Check_index(2,Id$,Row)
6748        IF Row=0 THEN
6750          BEEP
6752          DISP "Buffer not found"
6754          WAIT 1
6756        END IF
6758      UNTIL Row<>0
6760    ELSE
6762      IF Row=0 THEN
6764        Check_index(2,Id$,Row)
6766        IF Row=0 THEN
6768          Row=-1
6770          PRINT "Cannot find buffer ";Id$;" in Plot_buff"
6772          SUBEXIT
6774        END IF
6776      END IF
6778    END IF
6780    !
6782    Buff_to_temp(Row,Id$,Tempdata(*))
6784    Plot_set(Plot_pos)
6786    !
6788    Xmin=Buff_start(Row,2)
6790    Xmax=Buff_start(Row,2)+Buff_points(Row,2)/Buff_freq(Row,2)
6792    Ymin=MIN(Tempdata(*))
6794    Ymax=MAX(Tempdata(*))
6796    Start=Buff_time(Row,2)
6798    Lt_title$=Buff_title$(Row,2)
6800    Rt_title$="Series "&Test_hdr$[1,3]&" Test "&VAL$(VAL(Test_hdr$[4,5]))
6802    Xlbl$="Time (sec)"
6804    Ylbl$=Buff_units$(Row,2)
6806    Message1$=""
6808    Message2$=""
6810    Auto=Auto_scale
6812    !
6814    Plot_label(Xmin,Xmax,Ymin,Ymax,Lt_title$,Rt_title$,Xlbl$,Ylbl$,0,0,Messa
6816    Plot_time(Tempdata(*),1/Buff_freq(Row,2),Buff_time(Row,2),Color(1),Line(
6818    !
6820    DEALLOCATE Tempdata(*)
```

```
6822  SUBEND
6824  !________________________________________________________________________
6826  !
6828 Plot_buff_1vs2:SUB Plot_buff_1vs2(Plot_pos,Row1,Id1$,Row2,Id2$,Errplot)
6830  !
6832  ! Plot Buffer 1 (y axis) vs. Buffer 2 (x axis)
6834  !
6836  ! INPUTS:
6838  !     Plot_pos    - position of plot on page
6840  !     Row1,Row2   - row of buffers in index
6842  !     Id1$,id2$   - Id$ of buffers to be plotted
6844  !
6846  ! OUTPUTS:
6848  !     Errplot     - Returns 1 if buffs not found
6850  !
6852  ! CALLS:
6854  !     Buff_to_temp
6856  !     Check_index
6858  !     Plot_label
6860  !     Plot_set
6862  !     Plot_xy
6864  !========================================================================
6866    OPTION BASE 1
6868    COM /Index_string/ Buff_id$(*),Buff_title$(*),Buff_units$(*)
6870    COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
6872    COM /Index_real/ Buff_freq(*),Buff_gain(*),Buff_offset(*),Buff_time(*)
6874    COM /Buff_defaults/ Buff_ingain
6876    COM /Raw_defaults/ INTEGER No_avg,Skip,REAL Start_time,Stop_time
6878    COM /Graph_stuff/ Color(6),Line(6),Overlay_no,Full_screen,Split_format,A
6880    COM /Msus/ Msus_raw1$,Msus_raw2$,Msus_buff$,Msus_ext$,Test_hdr$
6882    COM /Autosequence/ INTEGER Seq_no,Seq_flag,Sequence$(*)
6884    !-----------------------------------------------------------------------
6886    ALLOCATE Data_1(FNSize_acc),Data_2(FNSize_acc)
6888    ALLOCATE Lt_title$[50],Rt_title$[50],Xlbl$[20],Ylbl$[20]
6890    !
6892    Errplot=0
6894    Overlay_no=1
6896    Id1$=UPC$(Id1$)
6898    Id2$=UPC$(Id2$)
6900    !
6902    IF Id1$="" THEN
6904      REPEAT
6906        BEEP
6908        INPUT "ID of Buffer to be plotted on y axis?",Id1$
6910        Check_index(2,Id1$,Row1)
6912        IF Row1=0 THEN
6914          BEEP
6916          DISP "Buffer not found"
6918          WAIT 1
6920        END IF
6922      UNTIL Row1<>0
6924    ELSE
6926      IF Row1=0 THEN
6928        Check_index(2,Id1$,Row1)
6930        IF Row1=0 THEN
6932          PRINT "Cannot find buffer ";Id1$;" in Plot_buff"
6934          Row1=-1
6936          Errplot=1
6938          SUBEXIT
6940        END IF
```

```
6942      END IF
6944    END IF
6946    !
6948    IF Id2$="" THEN
6950      REPEAT
6952        BEEP
6954        INPUT "ID of Buffer to be plotted on x axis?",Id2$
6956        Check_index(2,Id2$,Row2)
6958        IF Row2=0 THEN
6960          BEEP
6962          DISP "Buffer not found"
6964          WAIT 1
6966        END IF
6968      UNTIL Row2<>0
6970    ELSE
6972      IF Row2=0 THEN
6974        Check_index(2,Id2$,Row2)
6976        IF Row2=0 THEN
6978          PRINT "Cannot find buffer ";Id2$;" in Plot_buff"
6980          Errplot=1
6982          Row2=-1
6984          SUBEXIT
6986        END IF
6988      END IF
6990    END IF
6992    !
6994    ! Check for consistency between buffers
6996    !
6998    IF Buff_freq(Row1,2)<>Buff_freq(Row2,2) THEN
7000      PRINT "Sample frequency inconsistency between ";Id1$;" and ";Id2$
7002      PRINT "Cannot plot xy "
7004      Errplot=1
7006      SUBEXIT
7008    END IF
7010    IF Buff_time(Row1,2)<>Buff_time(Row2,2) THEN
7012      PRINT "Start time inconsistency between ";Id1$;" and ";Id2$
7014      PRINT "Cannot plot xy "
7016      Errplot=1
7018      SUBEXIT
7020    END IF
7022    !
7024    Buff_to_temp(Row1,Id1$,Data_1(*))
7026    Buff_to_temp(Row2,Id2$,Data_2(*))
7028    !
7030    Ymin=MIN(Data_1(*))
7032    Ymax=MAX(Data_1(*))
7034    Xmin=MIN(Data_2(*))
7036    Xmax=MAX(Data_2(*))
7038    !
7040    Lt_title$=Buff_id$(Row1,2)&" vs. "&Buff_id$(Row2,2)
7042    Rt_title$="Series "&Test_hdr$[1,3]&" Test "&VAL$(VAL(Test_hdr$[4,5]))
7044    Ylbl$=Buff_units$(Row1,2)
7046    Xlbl$=Buff_units$(Row2,2)
7048    Message1$=""
7050    Message2$=""
7052    !
7054    Auto=Auto_scale
7056    Plot_set(Plot_pos)
7058    !
7060    IF Seq_flag=1 THEN              ! Temporarily disable Seq_flag
```

```
7062      Temp_seq=1                       ! to avoid setting x axis to time window.
7064      Seq_flag=0
7066    ELSE
7068      Temp_seq=0
7070    END IF
7072    !
7074    CALL Plot_label(Xmin,Xmax,Ymin,Ymax,Lt_title$,Rt_title$,Xlbl$,Ylbl$,0,0,
7076    !
7078    IF Temp_seq=1 THEN Seq_flag=1 ! OK, put Seq_flag back to where it was.
7080    !
7082    Plot_xy(Data_1(*),Data_2(*),Color(1),Line(1),"")
7084    DEALLOCATE Ylbl$,Xlbl$,Rt_title$,Lt_title$
7086    DEALLOCATE Data_2(*),Data_1(*)
7088  SUBEND
7090  !_____________________________________________________________________________
7092  !
7094 Plot_int_raw:SUB Plot_int_raw(Plot_pos,Row,Ch_id$,INTEGER No_avg,Skip,REAL
7096  !
7098  ! This gives a simplified data plot from a raw data channel.
7100  ! The raw values directly from the data file are plotted versus
7102  ! sample number.
7104  ! Input variables are identical to the same ones used in Plot_raw.
7106  !============================================================================
7108    OPTION BASE 1
7110    COM /Index_string/ Buff_id$(*),Buff_title$(*),Buff_units$(*)
7112    COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
7114    COM /Index_real/ Buff_freq(*),Buff_gain(*),Buff_offset(*),Buff_time(*)
7116    COM /Graph_stuff/ Color(*),Line(*),Overlay_no,Full_screen,Split_format,A
7118    COM /Graph_limits/ Viewxmin,Viewxmax,Viewymin,Viewymax,Xmin,Xmax,Ymin,Ym
7120    !-------------------------------------------------------------------------
7122    DIM Lt_title$[40],Rt_title$[40],Xlbl$[20],Ylbl$[20]
7124    ALLOCATE INTEGER Intdata(FNSize_acc)
7126    ALLOCATE Title$[40]
7128    INTEGER P
7130    !
7132    IF Row=-1 THEN SUBEXIT
7134    IF Ch_id$<>"" THEN
7136      IF Row=0 THEN
7138        Check_index(1,Ch_id$,Row)
7140        IF Row=0 THEN
7142          Row=-1
7144          PRINT Ch_id$;" not found in Plot_raw"
7146          SUBEXIT
7148        END IF
7150      END IF
7152    ELSE
7154      REPEAT
7156        BEEP
7158        INPUT "ID of Raw data file to be plotted?",Ch_id$
7160        Check_index(1,Ch_id$,Row)
7162        IF Row=0 THEN
7164          BEEP
7166          DISP "Raw data file not found"
7168          WAIT 1
7170        END IF
7172      UNTIL Row>0
7174    END IF
7176    !
7178    IF Skip=0 THEN
7180      Io_factor=No_avg
```

```
7182    ELSE
7184      Ic_factor=Skip
7186    END IF
7188    !
7190    Time_offset=Start_time
7192    Start_sample=FNStart_sample(Start_time,Row,1)
7194    IF Start_sample<1 THEN
7196      Time_offset=Time_offset-(Start_sample-1)/Buff_freq(Row,1)
7198      Start_sample=1
7200    END IF
7202    !
7204    Stop_sample=FNStop_sample(Stop_time,Row,1)
7206    Raw_to_int(Row,Ch_id$,Intdata(*),No_avg,Skip,Start_sample,Stop_sample)
7208    !
7210    !Plot_set(0)
7212    Clear_screen
7214    !---------------------!
7216    Xmin=1
7218    Xmax=SIZE(Intdata,1)
7220    Ymin=-2048
7222    Ymax=2048
7224    !---------------------!
7226    Title$=Buff_title$(Row,1)
7228    !---------------------!
7230    X_gdu=100*MAX(1,RATIO)
7232    Y_gdu=100*MAX(1,1/RATIO)
7234    Vwxmin=.125*X_gdu
7236    Vwxmax=.875*X_gdu
7238    Vwymin=.100*Y_gdu
7240    Vwymax=.800*Y_gdu
7242    !---------------------!
7244    VIEWPORT 0,RATIO*100,0,100
7246    WINDOW 0,RATIO*100,0,100
7248    !---------------------!
7250    ON KEY 5,14 RECOVER Exit_plot
7252    ALPHA OFF
7254    GRAPHICS ON
7256    !---------------------!
7258    LORG 5
7260    CSIZE 6
7262    MOVE RATIO*100/2,95
7264    LABEL (Title$)
7266    !---------------------!
7268    VIEWPORT Vwxmin,Vwxmax,Vwymin,Vwymax
7270    !VIEWPORT 12,105,7,83
7272    WINDOW Xmin,Xmax,-2048,2048
7274    CLIP ON
7276    AXES Xmax/5,512,0,0,10,1,3
7278    AXES Xmax/5,4096,0,-2048,10,5,3
7280    FRAME
7282    CLIP OFF
7284    !---------------------!
7286    CSIZE 3
7288    DEG
7290    LDIR 0
7292    LORG 8
7294    FOR I=-2048 TO 2048 STEP 512
7296      MOVE Xmin-.01*(Xmax-Xmin),I
7298      LABEL USING "$,K";DROUND(I,4)
7300    NEXT I
```

```
7302     !---------------------!
7304     LORG 6
7306     FOR I=0 TO Xmax STEP Xmax/5
7308       MOVE I,-2048-.01*4096
7310       LABEL USING "$,K";DROUND(I,4)
7312     NEXT I
7314     LORG 2
7316     !---------------------!
7318     !GSTORE Screen(*)
7320     !GLOAD Screen(*)
7322     !WINDOW 1,Xmax,1,Ymax
7324     WINDOW 0,Xmax,-2048,2048
7326     FOR P=1 TO Xmax
7328       PLOT P,Intdata(P)
7330     NEXT P
7332 Exit_plot:OFF KEY 14
7334     !GSTORE Screen(*)
7336   SUBEND
7338   !_____________________________________________________________________________
7340   !
7342 Plot_label:SUB Plot_label(Data_xmin,Data_xmax,Data_ymin,Data_ymax,Lt$,Rt$,X
7344   !
7346   !  Plot_label                        Last mod: 02/08/86
7348   !
7350   !  Purpose: to modify positioning of labels, and system of positioning.
7352   !
7354   !  This subprogram sets up the plot with titles and labels on the
7356   !  axes.  The variables in the viewport COM block must be set.
7358   !  The number of ticks, number of minor ticks per major tick,
7360   !  and the number of values on each axis can be specified
7362   !  in the optional parameters.
7364   !
7366   !  VARIABLES:
7368   !         Data_xmin ->      These are separate from Xmin->Xmax in order
7370   !               Data_ymax   to prevent confusion  with them.
7372   !         Lt$               Top left title on plot
7374   !         Rt$               Top right title on plot
7376   !         Xlbl$             Label for x-axis
7378   !         Ylbl$             Label for y-axis
7380   !         Xaxis,Yaxis       Coordinates where the x and y axes meet
7382   !         Message1+2$       Messages to be printed in top right corner
7384   !         Auto              If 1, then autoscaling on
7386   !         Xtick             Number of ticks on the x axis
7388   !         Ytick             Number of ticks on the y axis
7390   !         Xmajor,Ymajor     Number of minor ticks per major tick
7392   !         Xnos,Ynos         Number of values on each axis
7394   !=============================================================================
7396     OPTION BASE 1
7398     COM /Graph_limits/ Viewxmin,Viewxmax,Viewymin,Viewymax,Xmin,Xmax,Ymin,Ym
7400     COM /Hardware/ Prt_address,Current_prt,Computer$
7402     !---------------------------------------------------------------------------
7404     !
7406     ! This sets variables according to the number of parameters passed.
7408     !
7410     Xtick=100                                       !Initialize defaults
7412     Ytick=100
7414     Xmajor=4
7416     Ymajor=4
7418     Xvalues=5
7420     Yvalues=5
```

```
7422     !
7424     SELECT NPAR                                         !Set variables
7426     CASE 13
7428       !Drop out
7430     CASE 14
7432       Xtick=X_tk
7434     CASE 15
7436       Xtick=X_tk
7438       Ytick=Y_tk
7440     CASE 16
7442       Xtick=X_tk
7444       Ytick=Y_tk
7446       Xmajor=X_mj
7448     CASE 17
7450       Xtick=X_tk
7452       Ytick=Y_tk
7454       Xmajor=X_mj
7456       Ymajor=Y_mj
7458     CASE 18
7460       Xtick=X_tk
7462       Ytick=Y_tk
7464       Xmajor=X_mj
7466       Ymajor=Y_mj
7468       Xvalues=Xno
7470     CASE 19
7472       Xtick=X_tk
7474       Ytick=Y_tk
7476       Xmajor=X_mj
7478       Ymajor=Y_mj
7480       Xvalues=Xno
7482       Yvalues=Yno
7484     END SELECT
7486     GRAPHICS OFF
7488     ALPHA ON
7490     !
7492     ! If desired call Auto_scale subprogram to set limits and tick marks.
7494     !
7496     IF Auto<>0 THEN
7498       Auto_scale(Data_xmin,Data_xmax,Data_ymin,Data_ymax,Auto,Xtick,Ytick,Xm
7500     END IF
7502     !
7504     Xmin=Data_xmin
7506     Xmax=Data_xmax
7508     Ymin=Data_ymin
7510     Ymax=Data_ymax
7512     !
7514     LINE TYPE 1
7516     PEN 1
7518     ALPHA OFF
7520     GRAPHICS ON
7522    !----------------------------------!
7524    ! Initialize viewport to outside   !
7526    ! limits.                          !
7528    !----------------------------------!
7530     Clear_screen
7532     GLOAD Screen(*)
7534     VIEWPORT Viewxmin,Viewxmax,Viewymin,Viewymax
7536     WINDOW 0,100,0,100
7538    !----------------------------------!
7540    ! Labels Lt$ in the top left       !
```

```
7542 ! corner of the viewport in thick !
7544 ! letters.                        !
7546 !--------------------------------!
7548   LORG 2
7550   CSIZE 4
7552   FOR I=-.2 TO .2 STEP .1
7554     MOVE 5+I,96
7556     LABEL (Lt$)
7558   NEXT I
7560 !--------------------------------!
7562 ! Labels Rt$ in the top right     !
7564 ! corner of the viewport in thick !
7566 ! letters.                        !
7568 !--------------------------------!
7570   LORG 9
7572   FOR I=-.2 TO .2 STEP .1
7574     MOVE 95+I,96
7576     LABEL (Rt$)
7578   NEXT I
7580 !--------------------------------!
7582 ! Labels the Y axis, printed      !
7584 ! vertically.                     !
7586 !--------------------------------!
7588   MOVE 1,50
7590   LORG 6
7592   DEG
7594   LDIR 90
7596   CSIZE 3
7598   LABEL (Ylbl$)
7600 !--------------------------------!
7602 ! Labels the X axis, printed      !
7604 ! horizontally.                   !
7606 !--------------------------------!
7608   LDIR 0
7610   LORG 4
7612   MOVE 50,1
7614   LABEL (Xlbl$)
7616 !--------------------------------!
7618 ! Labels Msg1$ in the top right   !
7620 ! corner of the viewport.         !
7622 !--------------------------------!
7624   MOVE 100,96
7626   CSIZE 2
7628   LORG 9
7630   LABEL Msg1$&" "
7632 !--------------------------------!
7634 ! Labels Msg2$ in the top right   !
7636 ! corner of the viewport.         !
7638 !--------------------------------!
7640   MOVE 100,81
7642   LABEL Msg2$&" "
7644 !--------------------------------!
7646 ! Set window to Xmin,Xmax,Ymin,   !
7648 ! and Ymax.  Viewport set to a    !
7650 ! portion of values in COM block. !
7652 !--------------------------------!
7654   VIEWPORT Viewxmin+12,Viewxmax-15,Viewymin+7,Viewymax-7
7656   WINDOW Xmin,Xmax,Ymin,Ymax
7658   CLIP ON
7660 !--------------------------------!
```

```
7662  ! This draws the axes.              !
7664  !----------------------------------!
7666    IF Xmin<>0 OR Ymin<>0 THEN
7668      AXES (Xmax-Xmin)/Xtick*Xmajor,(Ymax-Ymin)/Ytick*Ymajor,Xaxis,Yaxis,1,Y
7670    END IF
7672    AXES (Xmax-Xmin)/Xtick,(Ymax-Ymin)/Ytick,Xmin,Ymin,Xmajor,Ymajor,3
7674    FRAME
7676    CLIP OFF
7679  !----------------------------------!
7680  ! This labels the values on the    !
7682  !              Y axis.             !
7684  !----------------------------------!
7686    CSIZE 3
7689    DEG
7690    LDIR 0
7692    LORG 8
7694    FOR I=Ymin TO Ymax STEP (Ymax-Ymin)/Yvalues
7696      MOVE Xmin-.01*(Xmax-Xmin),I
7698      LABEL USING "$,K";DROUND(I,3)
7700    NEXT I
7702  !----------------------------------!
7704  ! This labels the values on the    !
7706  ! X axis, according to the         !
7708  ! greatest number of digits present
7710  !----------------------------------!
7712    LORG 6
7714    Left=1
7716    Right=0
7718    FOR I=Xmin TO Xmax*1.01 STEP (Xmax-Xmin)/Xvalues
7720                  ! 1.01 factor is to avoid roundoff errors
7722      Num$=VAL$(I)
7724  !-----------------------------NEW WAY..
7726      Dec_pos=POS(Num$,".")
7729      IF Dec_pos<>0 THEN
7730        Left=MAX(Left,Dec_pos-1)
7732        Right=MAX(Right,LEN(Num$)-Dec_pos)
7734      ELSE
7736        Left=MAX(Left,LEN(Num$))
7739      END IF
7740  !-----------------------------OLD WAY...
7742  !   FOR J=1 TO LEN(Num$)
7744  !     IF Num$[J,J]="." THEN
7746  !       IF J-1>Left THEN
7748  !         Left=J-1
7750  !       END IF
7752  !       IF LEN(Num$)-J>Right THEN
7754  !         Right=LEN(Num$)-J
7756  !       END IF
7758  !     END IF
7760  !   NEXT J
7762  !--------------------------
7764    NEXT I
7766    FOR I=Xmin TO Xmax*1.01 STEP (Xmax-Xmin)/Xvalues
7768      MOVE I,Ymin-.01*(Ymax-Ymin)
7770      LABEL USING "$,K";DROUND(I,Left+Right)
7772    NEXT I
7774    LORG 2
7776    !----------------------------!
7779 Exit_plot: !
7780    GSTORE Screen(*)
```

```
7782  SUBEND
7784  !________________________________________________________________________
7786  !
7788 Plot_raw:SUB Plot_raw(Plot_pos,Row,Ch_id$,INTEGER No_avg,Skip,REAL Start_ti
7790  !
7792  ! Plots data from given raw data file (Ch_id$)
7794  !  INPUTS: (those not listed are in accompanying documentation)
7796  !          Plot_pos: 0 for full screen
7798  !                    1 for top or left splitscreen
7800  !                    2 for bottom or right splitscreen
7802  !========================================================================
7804    OPTION BASE 1
7806    COM /Index_string/ Buff_id$(*),Buff_title$(*),Buff_units$(*)
7808    COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
7810    COM /Index_real/ Buff_freq(*),Buff_gain(*),Buff_offset(*),Buff_time(*)
7812    COM /Graph_stuff/ Color(*),Line(*),Overlay_no,Full_screen,Split_format,A
7814    COM /Msus/ Msus_raw1$,Msus_raw2$,Msus_buff$,Msus_ext$,Test_hdr$
7816    !-----------------------------------------------------------------------
7818    DIM Lt_title$[40],Rt_title$[40],Xlbl$[20],Ylbl$[20]
7820    ALLOCATE Tempdata(FNSize_acc)
7822    Overlay_no=1
7824    Ch_id$=UPC$(Ch_id$)
7826    IF Row=-1 THEN SUBEXIT
7828    IF Ch_id$<>"" THEN
7830      IF Row=0 THEN
7832        Check_index(1,Ch_id$,Row)
7834        IF Row=0 THEN
7836          Row=-1
7838          PRINT Ch_id$;" not found in Plot_raw"
7840          SUBEXIT
7842        END IF
7844      END IF
7846    ELSE
7848      REPEAT
7850        BEEP
7852        INPUT "ID of Raw data file to be plotted?",Ch_id$
7854        Check_index(1,Ch_id$,Row)
7856        IF Row=0 THEN
7858          BEEP
7860          DISP "Raw data file not found"
7862          WAIT 1
7864        END IF
7866      UNTIL Row>0
7868    END IF
7870    !----------------------------!
7872    ! Calculate start, stop sample nos.
7874    ! Load data from disk file.
7876    !----------------------------!
7878    Time_offset=Start_time
7880    Start_sample=FNStart_sample(Start_time,Row,1)
7882    Stop_sample=FNStop_sample(Stop_time,Row,1)
7884    Raw_to_temp(Row,Ch_id$,Tempdata(*),No_avg,Skip,Start_sample,Stop_sample)
7886    IF Row=-1 THEN SUBEXIT
7888    !----------------------------!
7890    ! Calculate sample rate reduction factor
7892    !----------------------------!
7894    IF Skip=0 THEN
7896      Io_factor=No_avg
7898    ELSE
7900      Io_factor=Skip
```

```
7902    END IF
7904    !-----------------------------!
7906    ! Plot it!
7908    !-----------------------------!
7910    Plot_set(2*Split_format+Plot_pos)
7912    !
7914    Xmin=Start_time
7916    Xmax=Stop_time
7918    Ymin=MIN(Tempdata(*))
7920    Ymax=MAX(Tempdata(*))
7922    Lt_title$=Buff_title$(Row,1)
7924    Rt_title$="Series "&Test_hdr$[1,3]&" Test "&VAL$(VAL(Test_hdr$[4,5]))
7926    Xlbl$="Time (sec)"
7928    Ylbl$=Buff_units$(Row,1)
7930    Message1$=""
7932    Message2$=""
7934    Auto=Auto_scale
7936    Plot_label(Xmin,Xmax,Ymin,Ymax,Lt_title$,Rt_title$,Xlbl$,Ylbl$,0,0,Messa
7938    Plot_time(Tempdata(*),Io_factor/Buff_freq(Row,1),Time_offset,Color(Overl
7940  SUBEND
7942  !________________________________________________________________________
7944  !
7946 Plot_set:SUB Plot_set(N)
7948  !
7950  !  Plot_set                           Last_mod: 02/28/86
7952  !
7954  !  Purpose:  to adjust the limits of the viewport
7956  !
7958  !  This sets the viewport that the data will be plotted on.
7960  !  INPUT: N - Plot position:
7962  !                                0= Full screen
7964  !                                1= Top of screen
7966  !                                2= Bottom
7968  !                                3= Left
7970  !                                4= Right
7972  !  Sets the values of:
7974  !                             Viewxmin,Viewxmax,Viewymin,Viewymax
7976  !========================================================================
7978    OPTION BASE 1
7980    COM /Graph_limits/ Viewxmin,Viewxmax,Viewymin,Viewymax,Xmin,Xmax,Ymin,Ym
7982    COM /Graph_stuff/ Color(*),Line(*),Overlay_no,Full_screen,Split_format,A
7984    COM /Hardware/ Prt_address,Current_prt,Computer$
7986    !-----------------------------------------------------------------------
7988    INTEGER I,J
7990    X_gdu=100*MAX(1,RATIO)
7992    Y_gdu=100*MAX(1,1/RATIO)
7994    X_limits=SIZE(Screen,2)
7996    Y_limits=SIZE(Screen,1)
7998    !-----------------------------!
8000    ! Set Ext_flag to 1 if external plotter is being used
8002    !-----------------------------!
8004    Plotter$=SYSTEM$("PLOTTER IS")
8006    IF Plotter$[1,1]="7" THEN
8008      Ext_flag=1
8010    ELSE
8012      Ext_flag=0
8014    END IF
8016    !-----------------------------!
8018    IF Computer$="9816" AND (N=3 OR N=4) AND Ext_flag=0 THEN
8020      PRINT "Left/right splitscreen plots not available for 9816"
```

```
8022        WAIT 1
8024        N=N-2
8026      END IF
8028      !-----------------------------!
8030      DISP "Clearing graphics screen memory"
8032      SCLEAR
8034      Clear_screen
8036      !-----------------------------!
8038      ! Clear complete Screen array if
8040      ! present OR previous plot was fullscreen.
8042      !-----------------------------!
8044      IF Full_screen=0 OR N=0 THEN
8046        MAT Screen= (0)
8048      END IF
8050      !-----------------------------!
8052      ! Set viewport parameters and
8054      ! clear part of Screen(*) if nec.
8056      !-----------------------------!
8058      SELECT N
8060      CASE 0
8062        Viewxmin=0.*X_gdu
8064        Viewxmax=1.00*X_gdu
8066        Viewymin=0.*Y_gdu
8068        Viewymax=.95*Y_gdu
8070        !-----------------------------!
8072        !  n=1: Plot top              !
8074        !-----------------------------!
8076      CASE 1
8078        Viewxmin=.010*X_gdu
8080        Viewxmax=.990*X_gdu
8082        Viewymin=.450*Y_gdu
8084        Viewymax=.900*Y_gdu
8086        FOR I=INT(.075*Y_limits) TO INT(.535*Y_limits)
8088          FOR J=1 TO X_limits
8090            Screen(I,J)=0
8092          NEXT J
8094        NEXT I
8096        !-----------------------------!
8098        !  n=2: plot bottom           !
8100        !-----------------------------!
8102      CASE 2
8104        Viewxmin=.010*X_gdu
8106        Viewxmax=.990*X_gdu
8108        Viewymin=.010*Y_gdu
8110        Viewymax=.450*Y_gdu
8112        FOR I=1+INT(.535*Y_limits) TO Y_limits
8114          FOR J=1 TO X_limits
8116            Screen(I,J)=0
8118          NEXT J
8120        NEXT I
8122        !-----------------------------!
8124        ! N=3: left
8126        !-----------------------------!
8128      CASE 3
8130        Viewxmin=.010*X_gdu
8132        Viewxmax=.500*X_gdu
8134        Viewymin=.010*Y_gdu
8136        Viewymax=.900*Y_gdu
8138        FOR I=INT(.075*Y_limits) TO Y_limits
8140          FOR J=1 TO X_limits/2
```

```
8142          Screen(I,J)=0
8144        NEXT J
8146      NEXT I
8148      !----------------------------!
8150      ! N=4: Right                 !
8152      !----------------------------!
8154    CASE 4
8156      Viewxmin=.500*X_gdu
8158      Viewxmax=.990*X_gdu
8160      Viewymin=.010*Y_gdu
8162      Viewymax=.900*Y_gdu
8164      FOR I=INT(.075*Y_limits) TO Y_limits
8166        FOR J=1+X_limits/2 TO X_limits
8168          Screen(I,J)=0
8170        NEXT J
8172      NEXT I
8174    CASE ELSE
8176      DISP "ERROR IN Plot_set - IMPROPER PARAMETER"
8178      PAUSE
8180    END SELECT
8182    DISP
8184    !----------------------------!
8186    ! Put titles on the plot iff:
8188    !      Page_header is ON (1)
8190    !             AND
8192    !              (
8194    ! External plotter AND plot is full, top or left (N=0,1,3)
8196    !             OR
8198    !      It is a Fullscreen plot (N=0)
8200    !             OR
8202    !      Last plot was fullscreen
8204    !              )
8206    !----------------------------!
8208    IF Page_header=1 THEN
8210      IF N=0 OR Full_screen=0 OR (Ext_flag=1 AND (N=1 OR N=3)) THEN
8212        Plot_titles
8214      END IF
8216    END IF
8218    !----------------------------!
8220    VIEWPORT Viewxmin,Viewxmax,Viewymin,Viewymax
8222    Full_screen=N                    ! Store in COM block
8224   SUBEND
8226   !_______________________________________________________________________!
8228   SUB Plot_time(Acc1(*),Time_inc,Time_offset,Pencolor,Line_type,Desig$)
8230 Plot_time: !
8232   !----------------------------------------------------------------------!
8234   !  Plot_time                         Last mod: 02/08/86
8236   !
8238   !  Purpose:
8240   !
8242   !  This is the actual plotting for parameter vs. time plots
8244   !  The scale, labels, etc. must be set up previous to this.
8246   !
8248   !    VARIABLES: Acc1 - The data to be plotted.
8250   !           Time_inc - Time between points
8252   !           Xmax,Xmin,Ymax,Ymin - Same as plot label routines
8254   !           Pencolor - the color of the line.
8256   !           Desig$  - the designation to be used as a legend at the side
8258   !---------------------------------------------------------------
8260    OPTION BASE 1
```

```
8262    COM /Graph_limits/ Viewxmin,Viewxmax,Viewymin,Viewymax,Xmin,Xmax,Ymin,Ym
8264    !----------------------------!
8266    ! Load graphics screen from array.
8268    !----------------------------!
8270    GLOAD Screen(*)
8272    LINE TYPE Line_type
8274    CLIP ON
8276  !------------------------------
8278    IF SYSTEM$("PLOTTER IS")<>"3" AND SYSTEM$("PLOTTER IS")<>"6" THEN
8280      PEN Pencolor
8282    END IF
8284  !------------------------------
8286    I1=MAX(1,1+INT((Xmin-Time_offset)/Time_inc))
8288    I2=MIN(1+INT(Xmax/Time_inc),SIZE(Acc1,1))
8290    FOR I=I1 TO I2
8292      PLOT (Time_offset+I*Time_inc),(Acc1(I))
8294    NEXT I
8296  !------------------------------
8298    IF Desig$<>"" THEN
8300      CLIP OFF
8302      VIEWPORT Viewxmin,Viewxmax,Viewymin,Viewymax
8304      WINDOW 0,100,0,100
8306      MOVE 90,70
8308      PLOT 90,70-7*Pencolor
8310      PLOT 99,70-7*Pencolor
8312      LINE TYPE 1
8314      CSIZE 3
8316      LORG 2
8318      MOVE 91.5,67-7*Pencolor
8320      LABEL Desig$
8322      PENUP
8324      MOVE 0,0
8326      WINDOW Xmin,Xmax,Ymin,Ymax
8328      VIEWPORT Viewxmin+12,Viewxmax-15,Viewymin+7,Viewymax-7
8330    END IF
8332  !------------------------------
8334 Exit_plot: !
8336    GSTORE Screen(*)
8338    BEEP
8340  SUBEND
8342  !__________________________________________________________________________
8344  !
8346 Plot_titles:SUB Plot_titles
8348  !
8350  ! Plot the titles used at the top of each page.
8352  !==========================================================================
8354    OPTION BASE 1
8356    COM /Graph_limits/ Viewxmin,Viewxmax,Viewymin,Viewymax,Xmin,Xmax,Ymin,Ym
8358    !-----------------------------------------------------------------------
8360    DIM Lt$[50],Rt$[50],Ti$[50]
8362    !
8364    Ti$=""
8366    Rt$="ANALYSIS DATE:"&DATE$(TIMEDATE)
8368    Lt$="GEOTECHnical Resources Ltd."
8370    !
8372    PEN 1
8374    LINE TYPE 1
8376    VIEWPORT 0,100*RATIO,0,100
8378    WINDOW 0,100,0,100
8380    !
```

```
8382    LORG 5                                            !Title, top left
8384    CSIZE 4.5
8386    MOVE 50,98
8388    LABEL (Ti$)
8390    !
8392    LORG 8                                            !Right label, top right
8394    CSIZE 3.5
8396    MOVE 95,95
8398    LABEL (Rt$)
8400    !
8402    LORG 2                                            !Left label, top left
8404    CSIZE 3.5
8406    MOVE 5,95
8408    LABEL Lt$
8410    !
8412    GSTORE Screen(*)                                  !Store graphics screen
8414  SUBEND
8416  !______________________________________________________________________
8418  !
8420  Plot_xy:SUB Plot_xy(Acc1(*),Acc2(*),Pencolor,Line_type,Desig$)
8422  !
8424  !  Plot_xy                        Last_mod: 02/08/86
8426  !
8428  !  Purpose:
8430  !
8432  !  This plots Array2 vs. Array1.  The scales, labels, etc. must
8434  !  be set up previous to this.
8436  !
8438  !    VARIABLES: ACC1, ACC2 - The data in the buffers
8440  !            Xmax,Xmin,Ymax,Ymin - Same as plot label routines
8442  !            Pencolor - color of the line.
8444  !            Linetype - line type of the line.
8446  !            Desig$  - the designation to be used as a legend at the side
8448  !======================================================================
8450    OPTION BASE 1
8452    COM /Graph_limits/ Viewxmin,Viewxmax,Viewymin,Viewymax,Xmin,Xmax,Ymin,Ym
8454    !---------------------------------------------------------------------
8456    GLOAD Screen(*)
8458    LINE TYPE Line_type
8460    CLIP ON
8462  !-----------------------------
8464    IF SYSTEM$("PLOTTER IS")<>"3" AND SYSTEM$("PLOTTER IS")<>"6" THEN
8466      PEN Pencolor
8468    END IF
8470  !-----------------------------
8472    FOR I=1 TO MIN(SIZE(Acc1,1),SIZE(Acc2,1))
8474      PLOT (Acc2(I)),(Acc1(I))
8476    NEXT I
8478  !-----------------------------!
8480  !  Draw Legend                !
8482  !-----------------------------!
8484    IF Desig$<>"" THEN
8486      CLIP OFF
8488      VIEWPORT Viewxmin,Viewxmax,Viewymin,Viewymax
8490      WINDOW 0,100,0,100
8492      MOVE 90,70
8494      PLOT 90,70-6*Pencolor
8496      PLOT 99,70-6*Pencolor
8498      LINE TYPE 1
8500      LORG 2
```

```
8502      LABEL " "&VAL$(Line_type)
8504      PENUP
8506      MOVE 0,0
8508      WINDOW Xmin,Xmax,Ymin,Ymax
8510      VIEWPORT Viewxmin+12,Viewxmax-15,Viewymin+7,Viewymax-7
8512    END IF
8514    !
8516 Exit_plot:                                        !
8518    GSTORE Screen(*)
8520    BEEP
8522  SUBEND
8524  !__________________________________________________________________________
8526 Principal_e:SUB Principal_e(OPTIONAL Filename$)
8528  !
8530  ! This calculation module calculates the principal strains and their
8532  ! orientation ( P, Q, A respectively), given the input rosette.
8534  ! It generates three buffer files with the common prefix:
8536  !     '(window)' & 'PS' & '(rosette number)'
8538  ! to which is appended the suffix 'P', 'Q', and 'A'.
8540  !
8542  ! INPUT (if used) : Filename$
8544  ! The filename must consist of the rosette id (without the arm suffix)
8546  ! appended to the time window (1 or 2). See the 2 input prompts below.
8548  !==========================================================================
8550    OPTION BASE 1
8552    COM /Accumulators/ No_acc,Size_acc,Acc1(*),Acc2(*),Acc3(*),Acc4(*),Acc5(
8554    COM /Raw_defaults/ INTEGER No_avg,Skip,REAL Start_time,Stop_time
8556    COM /Buff_defaults/ Buff_ingain
8558    !-----------------------------------------------------------------------
8560    IF No_acc<6 THEN
8562      PRINT TABXY(1,19);"Oh come on now. Cannot calculate principal strain w
8564      SUBEXIT
8566    END IF
8568    !
8570    IF NPAR=0 OR Filename$="" THEN
8572      DISP CHR$(129)
8574      INPUT " Enter Rosette Id without the arm suffix e.g. '(Window)BR1' ",R
8576      DISP CHR$(128)
8578    END IF
8580    Rosette_id$=UPC$(Rosette_id$)
8582    !*
8584    !* Check if each rosette arm is present. If the file is available, load
8586    !* it into an accumulator; otherwise, exit. the rosette arm designations
8588    !* are A, B, and C, and the arm base is set to the ASCII equivalent of
8590    !* the first arm (A) less 1. On exit, create the buffer file prefix.
8592    !*
8593    Acc=0
8596    Arm_base=64
8597    Arm_id$=" "
8599    No_arms=3
8600    FOR Arm=1 TO No_arms
8601      Arm_id$=CHR$(Arm_base+Arm)
8602      Check_index(1,Rosette_id$&Arm_id$,Row)
8604      IF Row=0 THEN
8606        PRINT "Cannot find this rosette: ";Rosette_id$&Arm_id$
8608        SUBEXIT
8610      END IF
8612      Acc=Acc+1
8614      Raw_to_acc(0,Rosette_id$&Arm_id$,Acc,No_avg,Skip,Start_time,Stop_time)
8616    NEXT Arm
```

```
8618     Name$=Rosette_id$[1,1]&"PS"&Rosette_id$[4]
8620     !*
8622     !* Principal strain calculation formula:
8624     !* Ex,y = 0.5 * { E1 + E3 +/-
8626     !*           [ (E1 - E2)^2 + (2 * E2 - E1 - E3)^2 ] ^0.5 }
8628     !* Where E1, E2, E3 = strains of arms A, B, C respectively
8630     !* First find the square root (ROOT), then find the sum (P) and
8632     !* difference (Q) and save each in a buffer file. The buffer file
8634     !* suffixes are 'P' and 'Q', respectively.
8636     !*
8638     DISP "Calculating principal strains..."
8640     MAT Acc4= Acc1-Acc3                          ! (E1 - E3)^2
8642     MAT Acc4= Acc4 . Acc4
8644     MAT Acc5= Acc2*(2)                           ! (2 * E2 - E1 - E3)^2
8646     MAT Acc5= Acc5-Acc1
8648     MAT Acc5= Acc5-Acc3
8650     MAT Acc5= Acc5 . Acc5
8652     MAT Acc4= Acc4+Acc5                          ! (sum 'ROOT' contents)
8654     Matsqr(Acc4(*))                              ! (find 'ROOT' of sum)
8656     !
8658     MAT Acc5= Acc1+Acc3                          ! P = (E1 + E3 + 'ROOT')/2
8660     MAT Acc6= Acc5+Acc4
8662     MAT Acc6= Acc6*(.5)
8664     Acc_to_buff(6,Name$&"P","Principal Strain - P","uE",Buff_ingain,0)
8666     !
8668     MAT Acc6= Acc5-Acc4                          ! Q = (E1 + E3 - 'ROOT')/2
8670     MAT Acc6= Acc6*(.5)
8672     Acc_to_buff(6,Name$&"Q","Principal Strain - Q","uE",Buff_ingain,0)
8674     !*
8676     !* Acute angle calculation formula:
8678     !* Angle = 0.5 * { arctan [ (2 * E2 - E1 - E3) / (E1 - E3) ] }
8680     !* Where E1, E2, E3 = strains of arms A, B, C respectively
8682     !*       Y           = (2 * E2 - E1 - E3)
8684     !*       X           = E1 - E3
8686     !* The buffer file suffix is 'A'.
8688     !*
8690     DISP "Calculating principal strain angle..."
8692     MAT Acc4= Acc2*(2)                           ! Y = (2 * E2 - E1 - E3)
8694     MAT Acc4= Acc4-Acc1
8696     MAT Acc4= Acc4-Acc3
8698     MAT Acc5= Acc1-Acc3                          ! X = E1 - E3
8701     Matatn(Acc5(*),Acc4(*),Acc6(*))              ! 0.5 * [ arctan (Y / X) ]
8702     MAT Acc6= Acc6*(.5)
8704     Acc_to_buff(6,Name$&"A","Principal strain - Angle","Degrees",Buff_ingain
8706     DISP ""
8708   SUBEND
8710   !_______________________________________________________________________
8712 Print_index:SUB Print_index(Ind)
8714   !
8716   ! Prints buffer and raw data file index in a condensed format.
8718   !  Ind:  1 is raw files
8720   !        2 is buffer files
8722   ! Also see subprogram Dump_index.
8724   !========================================================================
8726     OPTION BASE 1
8728     COM /Index_string/ Buff_id$(*),Buff_title$(*),Buff_units$(*)
8730     COM /Index_real/ Buff_freq(*),Buff_gain(*),Buff_offset(*),Buff_time(*)
8732     COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
8734     COM /Hardware/ Prt_address,Current_prt,Computer$
8736     !----------------------------------------------------------------------
```

```
8738    INTEGER I
8740    Un$=CHR$(132)
8742    Nor$=CHR$(128)
8744    !
8746    SELECT Ind
8748      PRINT
8750    CASE 1
8752      PRINT "RAW   DATA   FILES"
8754      Lines=3
8756    CASE 2
8758      PRINT "BUFFER DATA  FILES"
8760      Lines=3
8762    END SELECT
8764    PRINT " ";Un$;"                              ";Nor$;"  ";Un$;"
8766    PRINT "|";Un$;"  ID  | Start | Dur.  ";Nor$;"||";Un$;"  ID  | Start | Du
8768 Index_image:IMAGE  #,1A,6A,1A,1X,DDDD.D,1A,1X,DDDD.D,1A
8770    !
8772    FOR I=1 TO No_buffers(Ind)+2 STEP 3
8774      IF I>No_buffers(Ind) THEN GOTO No_more_buffers
8776      PRINT USING Index_image;"|";Buff_id$(I,Ind);"|";Buff_time(I,Ind);"|";B
8778      IF I+1>No_buffers(Ind) THEN
8780        PRINT USING Index_image;"|";"";"|";0;"|";0;"|"
8782      ELSE
8784        PRINT USING Index_image;"|";Buff_id$(I+1,Ind);"|";Buff_time(I+1,Ind)
8786      END IF
8788      IF I+2>No_buffers(Ind) THEN
8790        PRINT USING Index_image;"|";"";"|";0;"|";0;"|"
8792      ELSE
8794        PRINT USING Index_image;"|";Buff_id$(I+2,Ind);"|";Buff_time(I+2,Ind)
8796      END IF
8798      PRINT
8800      Lines=Lines+1
8802      IF Lines=18 AND Current_prt=CRT THEN
8804        Lines=0
8806        PRINT CHR$(129);" Press Return ";CHR$(128)
8808        Wait_for_key
8810      END IF
8812    NEXT I
8814 No_more_buffers:!
8816    PRINT "|";Un$;"      |       |       ";Nor$;"||";Un$;"      |       |
8818    PRINT
8820  SUBEND
8822  !______________________________________________________________________
8824 Raw_to_acc:SUB Raw_to_acc(Row,Id$,Acc_no,INTEGER No_avg,Skip,REAL Start_tim
8826  !
8828  ! Transfers data from one the raw data files (Id$)
8830  ! to one of the accumulators (Acc_no)
8832  ! For list of input variables, see accompanying
8834  ! documentation.
8836  !======================================================================
8838    OPTION BASE 1
8840    COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
8842    COM /Index_real/ Buff_freq(*),Buff_gain(*),Buff_offset(*),Buff_time(*)
8844    !---------------------------------------------------------------------
8846    ALLOCATE Tempdata(FNSize_acc)
8848    !
8850    IF Row=0 THEN                                   !Check for data file
8852      Check_index(1,Id$,Row)
8854      IF Row=0 THEN
8856        Row=-1
```

```
8858       PRINT Id$;" not found in Raw_to_acc"
8860       SUBEXIT
8862     END IF
8864   END IF
8866   !
8868   Start_sample=FNStart_sample(Start_time,Row,1)
8870   Stop_sample=FNStop_sample(Stop_time,Row,1)
8872   !
8874   IF Start_sample<1 THEN
8876     PRINT "Time window incorrect for this channel:";Id$
8878     PRINT "No data put into accumulator ";Acc_no
8880   ELSE
8882     Raw_to_temp(Row,Id$,Tempdata(*),No_avg,Skip,Start_sample,Stop_sample)
8884     Temp_to_acc(Tempdata(*),Acc_no)
8886   END IF
8888   DEALLOCATE Tempdata(*)
8890 SUBEND
8892 !___________________________________________________________________________
8894 !
8896 Raw_to_buff:SUB Raw_to_buff(Row,Id_raw$,Id_buff$,INTEGER No_avg,Skip,REAL S
8898 !
8900 ! Transfers data directly from a raw file (Id_raw$) to a
8902 ! buffer (Id_buff$) according to window and decimation or
8904 ! averaging specified.
8906 ! Row is also a return variable specifying the row of the
8908 ! new buffer.
8910 !==========================================================================
8912   OPTION BASE 1
8914   COM /Index_string/ Buff_id$(*),Buff_title$(*),Buff_units$(*)
8916   COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
8918   COM /Index_real/ Buff_freq(*),Buff_gain(*),Buff_offset(*),Buff_time(*)
8920   !------------------------------------------------------------------------
8922   INTEGER Io_factor
8924   DIM Events(3)
8926   !
8928   DISP "Transferring ";Id_raw$;" to ";Id_buff$
8930   !
8932   Id_raw$=UPC$(Id_raw$)
8934   Id_buff$=UPC$(Id_buff$)
8936   !
8938   !-----------------------------!
8940   ! Check if raw file exists    !
8942   !-----------------------------!
8944   IF Row=-1 THEN SUBEXIT
8946   IF Row=0 THEN
8948     Check_index(1,Id_raw$,Row)
8950     IF Row=0 THEN
8952       Row=-1
8954       PRINT "Raw file ";Id_raw$;" not found."
8956       SUBEXIT
8958     END IF
8960   END IF
8962   !-----------------------------!
8964   ! Check if time window OK     !
8966   ! Calculate sample nos.       !
8968   !-----------------------------!
8970   ALLOCATE Tempdata(FNSize_acc)
8972   Events(1)=1
8974   Events(2)=Buff_event(Row,1)-Buff_start(Row,1)+1
8976   Events(3)=Buff_end(Row,1)-Buff_start(Row,1)+1
```

```
8978    !
8980    Start_sample=FNStart_sample(Start_time,Row,1)
8982    IF Start_sample<1 OR Start_sample>Buff_points(Row,1) THEN
8984      PRINT "Time window chosen incorrectly "
8986      PRINT "Cannot transfer Raw file ";Id_raw$;" to Buffer ";Id_buff$
8988      SUBEXIT
8990    END IF
8992    Stop_sample=FNStop_sample(Stop_time,Row,1)
8994    IF Start_sample>Stop_sample THEN
8996      PRINT "Time window chosen incorrectly "
8998      PRINT "Cannot transfer Raw file ";Id_raw$;" to Buffer ";Id_buff$
9000      SUBEXIT
9002    END IF
9004    Time_offset=Start_time
9006    !-----------------------------!
9008    ! Load raw data from disk     !
9010    !-----------------------------!
9012    Raw_to_temp(Row,Id_raw$,Tempdata(*),No_avg,Skip,Start_sample,Stop_sample
9014    !-----------------------------!
9016    ! Calculate sample rate reduction
9018    !-----------------------------!
9020    IF Skip=0 THEN
9022      Io_factor=No_avg
9024    ELSE
9026      Io_factor=Skip
9028    END IF
9030    !-----------------------------!
9032    ! Transfer to disk buffer file
9034    !-----------------------------!
9036    Temp_to_buff(Tempdata(*),Id_buff$,Buff_title$(Row,1),Buff_units$(Row,1),
9038    Row=Buff_row
9040    !
9042    DEALLOCATE Tempdata(*)
9044    DISP
9046  SUBEND
9048  !__________________________________________________________________________
9050 Raw_to_int:SUB Raw_to_int(Row,Id$,INTEGER Intdata(*),No_avg,Skip,REAL Start
9052  !
9054  !  Loads raw data from raw file Id$ and puts into intdata(*)
9056  !
9058  !       INPUT VARIABLES: Id$  - raw data channel designator.
9060  !                        Skip - used to select "1 of n" input samples
9062  !                             - if 0 or 1, no skip is used.
9064  !                             - if 1, no averaging is allowed.
9066  !                        Start_sample: desired start of data.
9068  !                        Stop_sample:  desired stop point in data.
9070  !                                      if -1, goes to end of file.
9072  !         INPUT/OUTPUT : Row - row of Id$ in index
9074  !                            - if 0, row has not been found yet.
9076  !                            - returns -1 if Id$ not found or other error.
9078  !                        No_avg - no. of input samples / 1 output sample.
9080  !                               - if 0, prompts user for no. to average.
9082  !                               - returns actual no. used for averaging.
9084  !                               - set to 1 if Skip (above) is <>0.
9086  !
9088  !               OUTPUT : Intdata: - THE DATA.
9090  !                        Index_row: - Row of index where data was found.
9092  !                                     0 if Id$ not found.
9094  !   A data table is contained in this subprogram which tells whether
9096  !   the data should be offset such that it is zero at a given event time
```

```
9098  !    (given by Buff_event). If the Channel id$ is found in this table,
9100  !    and if Buff_event has been defined (i.e. <>-999 ), then it is offset.
9102  !======================================================================
9104    OPTION BASE 1
9106    COM /Msus/ Msus_raw1$,Msus_raw2$,Msus_buff$,Msus_ext$,Test_hdr$
9108    COM /Index_real/ Buff_freq(*),Buff_gain(*),Buff_offset(*),Buff_time(*)
9110    COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
9112    !----------------------------------------------------------------------
9114 Raw_buff_size:                                      !
9116    INTEGER Inbuff(6000) BUFFER
9118    INTEGER I,Index_row
9120    !
9122 Offset_channels:                                    !
9124    DATA END
9126    !
9128    Data_block=FNSize_acc
9130    Id$=UPC$(Id$)
9132    !
9134    IF Row<0 THEN SUBEXIT
9136    IF Row=0 THEN
9138      Check_index(1,Id$,Row)
9140      IF Row=0 THEN
9142        Row=-1
9144        PRINT "Raw data file ";Id$;" not found"
9146        SUBEXIT
9148      END IF
9150    END IF
9152    !----------------------------!
9154    ! Perform exhaustive check of
9156    ! start and stop times.
9158    !----------------------------!
9160    Samples=Buff_points(Row,1)
9162    !
9164    IF Start_sample<1 THEN
9166      PRINT "Cannot load data file ";Id$
9168      Row=-1
9170      SUBEXIT
9172    END IF
9174    !
9176    IF Stop_sample<2 OR Stop_sample>Samples THEN
9178      Stop_sample=Samples
9180    END IF
9182    !
9184    IF Start_sample<0 THEN
9186      PRINT "Start time too early for this data channel - cannot load ";Id$
9188      Row=-1
9190      SUBEXIT
9192    END IF
9194    !
9196    IF Start_sample>Samples THEN
9198      PRINT "Start time chosen is too large - cannot load ";Id$
9200      Row=-1
9202      SUBEXIT
9204    END IF
9206    !
9208    IF Stop_sample<Start_sample THEN
9210      PRINT "Stop_sample<start_sample in Raw_to_int"
9212      Row=-1
9214      SUBEXIT
9216    END IF
```

```
9218    !--------------------------------------------!
9220    ! Open file, calculate req'd parameters.     !
9222    !--------------------------------------------!
9224    DISP "Loading ";Test_hdr$[1,5]&Id$&Msus_raw1$;
9226    ON ERROR GOSUB No_file_found
9228    ASSIGN @Raw TO Test_hdr$[1,5]&Id$&Msus_raw1$
9230    OFF ERROR
9232    !
9234    Window_size=Stop_sample-Start_sample+1
9236    Blocks=1+(Window_size DIV (1+Data_block))
9238    No_records=(Start_sample*2) DIV 256
9240    No_bytes=((Start_sample-1)*2) MOD 256
9242    !-----------------------------!
9244    !  Set file to selected start position
9246    !-----------------------------!
9248    CONTROL @Raw,5;No_records+1
9250    CONTROL @Raw,6;No_bytes+1
9252    !--------------------------------------------!
9254    !                                            !
9256    ! DETERMINE AVERAGING OR DATA DECIMATION FACTOR!
9258    !                                            !
9260    !--------------------------------------------!
9262 !  PRINT "No_avg,Skip=";No_avg,Skip
9264    !-----------------------------!
9266    !No_avg,Skip=                 !
9268    ! -1,     -1: Arbitrarily set Skip to minimum possible value.
9270    !-----------------------------!
9272    IF No_avg=-1 AND Skip=-1 THEN
9274      Skip=Blocks
9276    END IF
9278    !-----------------------------!
9280    ! 0,    0: Ask user
9282    !-----------------------------!
9284    IF No_avg=0 AND Skip=0 THEN
9286      REPEAT
9288        DISP
9290        DISP "Choose Decimation (+) or Averaging (-) factor: Minimum is +/-
9292        BEEP
9294        INPUT Factor
9296        IF SGN(Factor)=1 THEN
9298          Skip=Factor
9300        ELSE
9302          No_avg=-Factor
9304        END IF
9306      UNTIL (Skip>=Blocks) OR (No_avg>=Blocks)
9308      PRINT "No_avg,Skip=";No_avg,Skip
9310    END IF
9312    !-----------------------------!
9314    ! -1, ? : Decimation only (ask user)
9316    !-----------------------------!
9318    IF No_avg=-1 AND (Skip=0 OR Skip<Blocks) THEN
9320      REPEAT
9322        DISP
9324        DISP "MINIMUM Decimation factor is";Blocks;" TO 1 ; Enter factor";
9326        BEEP
9328        Skip=Blocks
9330        INPUT Skip
9332      UNTIL Skip>=Blocks
9334    END IF
9336    !-----------------------------!
```

```
9338      ! ?, -1 : Averaging only (ask user)
9340      !-----------------------------!
9342      IF Skip=-1 AND (No_avg=0 OR No_avg<Blocks) THEN
9344        REPEAT
9346          PRINT
9348          DISP "MINIMUM AVERAGING IS ";Blocks;" TO 1 ; Enter no. to average";
9350          BEEP
9352          No_avg=Blocks
9354          INPUT No_avg
9356        UNTIL No_avg>=Blocks
9358      END IF
9360      !------------------------------------------------!
9362      IF No_avg=1 OR Skip=1 THEN
9364      !-----------------------------!
9366      ! Data input, no averaging or skip
9368      !-----------------------------!
9370        DISP " directly"
9372        REDIM Intdata(Window_size)
9374        ON END @Raw GOTO Done
9376        ENTER @Raw;Intdata(*)
9378 Done:OFF END @Raw
9380      END IF
9382        !------------------------------------------------!
9384      IF No_avg>1 THEN
9386        !-----------------------------!
9388        ! Data input with averaging   !
9390        !-----------------------------!
9392        ALLOCATE INTEGER Avgbuff(Data_block,1),Sumbuff(Data_block)
9394        ASSIGN @Inbuff TO BUFFER Inbuff(*);FORMAT OFF
9396        DISP " averaging ";No_avg;" input samples to 1 output sample"
9398        Samples_left=Window_size
9400        FOR Block=1 TO Blocks
9402          Block_size=MIN(Data_block,Samples_left)
9404          Rows=INT(Block_size/No_avg)
9406          REDIM Avgbuff(Rows,No_avg)
9408          REDIM Sumbuff(Rows)
9410            !
9412          ON END @Raw GOTO Summit
9414          ENTER @Raw;Avgbuff(*)
9416 Summit:OFF END @Raw
9418            !
9420          MAT Sumbuff= RSUM(Avgbuff)
9422          OUTPUT @Inbuff;Sumbuff(*)
9424          Samples_left=Samples_left-Rows*No_avg
9426        NEXT Block
9428        ASSIGN @Inbuff TO *
9430        MAT Inbuff= Inbuff/(No_avg)
9432        REDIM Inbuff(Window_size DIV No_avg)
9434        MAT Intdata= Inbuff
9436        DEALLOCATE Sumbuff(*),Avgbuff(*)
9438      END IF
9440      !------------------------------------------------!
9442      IF Skip>1 THEN
9444      !-----------------------------!
9446      !  Data Input with Skip       !
9448      !-----------------------------!
9450        ALLOCATE INTEGER Origbuff(Data_block,1),Trnbuff(Data_block,1)
9452        ASSIGN @Inbuff TO BUFFER Inbuff(*);FORMAT OFF
9454        DISP " using skip factor of ";Skip
9456        Samples_left=Window_size
```

```
9458      FOR Block=1 TO Blocks
9460        Block_size=MIN(Data_block,Samples_left)
9462        Rows=INT(Block_size/Skip)
9464        REDIM Origbuff(Rows,Skip),Trnbuff(Rows,Skip)
9466        !
9468        ON END @Raw GOTO Gasmask
9470        ENTER @Raw;Origbuff(*)
9472 Gasmask:OFF END @Raw
9474        !
9476        MAT Trnbuff= TRN(Origbuff)
9478        REDIM Trnbuff(Rows,1)
9480        OUTPUT @Inbuff;Trnbuff(*)
9482        Samples_left=Samples_left-Rows*Skip
9484      NEXT Block
9486      ASSIGN @Inbuff TO *
9488      REDIM Inbuff(Window_size DIV Skip)
9490      MAT Intdata= Inbuff
9492      DEALLOCATE Trnbuff(*),Origbuff(*)
9494    END IF
9496    !-----------------------------!
9498    ! Offset data (if necessary)
9500    !-----------------------------!
9502    IF Buff_event(Row,1)<>-999 THEN
9504      RESTORE Offset_channels
9506      Flag=0
9508      REPEAT
9510        READ Offset_id$
9512        IF LEN(Offset_id$)<LEN(Id$) THEN
9514          IF UPC$(Id$[1,LEN(Offset_id$)])=UPC$(Offset_id$) THEN Flag=1
9516        END IF
9518      UNTIL Offset_id$="END"
9520      IF Flag=1 THEN
9522        MAT Intdata= Intdata-(Intdata(Buff_event(Row,1)))
9524        DISP "Offsetting data."
9526        WAIT .25
9528      END IF
9530    END IF
9532    !
9534    DISP
9536    ASSIGN @Inbuff TO *
9538    ASSIGN @Raw TO *
9540    SUBEXIT
9542    !++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
9544 No_file_found:                                       !
9546    PRINT "Eh? Cannot find data file ";Test_hdr$[1,5]&Id$&Msus_raw1$
9548    IF Msus_raw1$[7]="1" THEN
9550      Ans$=" "
9552      DISP CHR$(129)
9554      INPUT " LOAD new floppy? (then enter Y) or ABORT? (enter N) ",Ans$
9556      DISP CHR$(128)
9558      SELECT UPC$(Ans$[1])
9560      CASE "Y"
9562        RETURN
9564      CASE "N"
9566        Row=-1
9568        SUBEXIT
9570      CASE ELSE
9572        GOTO No_file_found
9574      END SELECT
9576    END IF
```

```
9578    Row=-1
9580   SUBEND
9582   !___________________________________________________________________________
9584 Raw_to_temp:SUB Raw_to_temp(Row,Id$,Tempdata(*),INTEGER No_avg,Skip,REAL St
9586   !
9588   !  Loads raw data from raw file Id$ and puts into Tempdata(*)
9590   !  Calls Raw_to_int.
9592   !
9594   !       INPUT VARIABLES: Id$ - raw data channel designator.
9596   !                        Skip - used to select "1 of n" input samples
9598   !                             - if 0 or 1, no skip is used.
9600   !                        Start_sample: desired start of data.
9602   !                        Stop_sample:  desired stop point in data.
9604   !                                      if -1, goes to end of file.
9606   !
9608   !       INPUT/OUTPUT: Row - row of Id$ in index
9610   !                         - if 0 as input, Id$ has not been found yet.
9612   !                         - outputs -1 if Id$ is not in index.
9614   !                     No_avg - no. of input samples / 1 output sample.
9616   !                            - if 0, prompts user for no. to average.
9618   !                            - returns actual no. used for averaging.
9620   !                            - set to 1 if Skip (above) is > 1 .
9622   !         OUTPUT:        Tempdata:  - engineering unit data.
9624   !
9626   !        GLOBAL EFFECTS:
9628   !        /Buff_defaults/ Sample_freq  : Are both changed to the
9630   !                        Events(*)    : appropriate value.
9632   !
9634   !=============================================================================
9636    OPTION BASE 1
9638    COM /Index_real/ Buff_freq(*),Buff_gain(*),Buff_offset(*),Buff_time(*)
9640    COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
9642    COM /Index_defaults/ Sample_freq,Events(3)
9644    !---------------------------------------------------------------------------
9646    ALLOCATE INTEGER Intdata(SIZE(Tempdata,1))
9648    !
9650    IF Row<0 THEN SUBEXIT
9652    IF Row=0 THEN
9654      Check_index(1,Id$,Row)
9656      IF Row=0 THEN
9658        Row=-1
9660        PRINT "Raw data file ";Id$;" not found"
9662        SUBEXIT
9664      END IF
9666    END IF
9668    !----------------------------!
9670    ! Load INTEGER data
9672    !----------------------------!
9674    Raw_to_int(Row,Id$,Intdata(*),No_avg,Skip,Start_sample,Stop_sample)
9676    IF Row=-1 THEN SUBEXIT
9678    !--------------------------------------!
9680    ! Convert using y=GAIN(x-OFFSET)
9682    !--------------------------------------!
9684    MAT Tempdata= Intdata
9686    MAT Tempdata= Tempdata-(Buff_offset(Row,1))
9688    MAT Tempdata= Tempdata*(Buff_gain(Row,1))
9690    DEALLOCATE Intdata(*)
9692    !--------------------------------------!
9694    ! Set new default values
9696    !--------------------------------------!
```

```
9698    IF Skip<>0 THEN
9700      Sample_freq=Buff_freq(Row,1)/Skip
9702    ELSE
9704      IF No_avg<>0 THEN
9706        Sample_freq=Buff_freq(Row,1)/No_avg
9708      ELSE
9710        Sample_freq=Buff_freq(Row,1)
9712      END IF
9714    END IF
9716    Events(1)=Buff_start(Row,1)    ! Start of valid data
9718    Events(2)=Buff_event(Row,1)    ! "Event"
9720    Events(3)=Buff_end(Row,1)      ! End of valid data
9722  SUBEND
9724 !____________________________________________________________________________
9726 !
9728 Read_index:SUB Read_index(Index$,Test_id$(*))
9730  !
9732  !This module reads a test index file, after which it prints out a file
9734  !summary to the current output device. Up to 99 tests can be held per
9736  !index.
9738  !
9740  !Inputs:
9742  !    Index$      = test index file name
9744  !Outputs:
9746  !    Test_id$(*) = array containing test names from the index file
9748  !===========================================================================
9750    OPTION BASE 1
9752    COM /Msus/ Msus_raw1$,Msus_raw2$,Msus_buff$,Msus_ext$,Test_hdr$
9754    !-------------------------------------------------------------------------
9756    ALLOCATE File$[10],Test_desc$[80],Test_time(99),INTEGER Test_status(99)
9758    INTEGER I
9760    !
9762    File$="*"
9764    MAT Test_id$= ("*")
9766    MAT Test_status= (-999)
9768    MAT Test_time= (-999)
9770    Test_desc$="*"
9772    !
9774    File$=UPC$(Index$)                                !Read index info
9776    PRINT "INDEX requested: ";CHR$(129);" "&File$&" ";CHR$(128)
9778    ON ERROR RECOVER No_file
9780    ASSIGN @File TO File$&Msus_raw1$
9782    OFF ERROR
9784    ON END @File RECOVER End_file
9786    ENTER @File;Test_desc$
9788    Clear_screen
9790    PRINT "Description: ";Test_desc$
9792    PRINT RPT$("-",46)
9794    !
9796    I=0                                               !Read index data (to EOF)
9798    LOOP
9800      I=I+1
9802      ENTER @File;Test_id$(I);Test_time(I);Test_status(I)
9804      SELECT Test_status(I)
9806      CASE 0
9808        Status$="OK"
9810      CASE 1
9812        Status$="NG"
9814      END SELECT
9816      Time$=TIME$(Test_time(I))
```

```
9818      Date$=DATE$(Test_time(I))
9820      PRINT Test_id$(I);"      ";Time$;"      ";Date$;"      ";Status$
9822    END LOOP
9824    !
9826 End_file:                                         !That's all, folks!
9828    OFF END @File
9830    ASSIGN @File TO *
9832    REDIM Test_id$(I-1)
9834    PRINT RPT$("-",46)
9836    DEALLOCATE File$,Test_desc$,Test_time(*),Test_status(*)
9838    SUBEXIT
9840    !+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
9842 No_file:                                          !File not found; try again
9844    OFF ERROR
9846    BEEP
9848    PRINT "INDEX file ";CHR$(129);" "&File$&Msus$&" ";CHR$(128);" not found!
9850    WAIT 1
9852    Request_test(Status)
9854  SUBEND
9856  !______________________________________________________________________
9858  !
9860 Read_stats:SUB Read_stats(Filename$)
9862  !
9864  ! Reads a previously created STATS file
9866  ! and print the results on the current printer.
9868  !=====================================================================
9870    OPTION BASE 1
9872    COM /Msus/ Msus_raw1$,Msus_raw2$,Msus_buff$,Msus_ext$,Test_hdr$
9874    COM /Hardware/ Prt_address,Current_prt,Computer$[10]
9876    COM /Index_string/ Buff_id$(*),Buff_title$(*),Buff_units$(*)
9878    !---------------------------------------------------------------------
9880    !
9882    ON ERROR GOTO Err_file
9884    ASSIGN @File TO Filename$&Msus_raw2$
9886    OFF ERROR
9888    ON END @File GOTO Done_for_now
9890    ENTER @File;Start_t;End_t
9892    OUTPUT Current_prt;RPT$("-",50)
9894    OUTPUT Current_prt;"           Statistics of Raw data files"
9896    OUTPUT Current_prt;"                (from stats file ";Filename$;")"
9898    OUTPUT Current_prt;"          Selected start time= ";Start_t;"   end time=
9900    OUTPUT Current_prt;RPT$(" ",10);"     MIN      MEAN        MAX   ";RPT$("
9902    OUTPUT Current_prt;RPT$("-",50)
9904    LOOP
9906      ENTER @File;Id$;Min;Mean;Max;Units$
9908      OUTPUT Current_prt USING Stat_image;Id$;Min;Mean;Max;Units$
9910      I=I+1
9912    END LOOP
9914 Stat_image:IMAGE 10A,3(1X,D.DDESZZ,1X),10A
9916 Done_for_now:      !
9918    OFF END @File
9920    ASSIGN @File TO *
9922    PRINT I;" records found in statistics file ";Filename$
9924    SUBEXIT
9926 Err_file:                    !
9928    IF ERRN=56 THEN
9930      PRINT "Cannot find statistics file ";Filename$
9932    ELSE
9934      PRINT ERRM$
9936    END IF
```

```
9938  SUBEND
9940  !_____________________________________________________________________
9942  !
9944 Request_test:SUB Request_test(Status)
9946  !
9948  !Outputs:
9950  !    Status
9952  !Calls:
9954  !    Read_index
9956  !=====================================================================
9958    OPTION BASE 1
9960    COM /Msus/ Msus_raw1$,Msus_raw2$,Msus_buff$,Msus_ext$,Test_hdr$
9962    !-------------------------------------------------------------------
9964    DIM Catstring$(10)[80],Test_index$[10],Test_hdrs$(99)[10]
9966    !
9968 Get_index:                                          !
9970    DISP CHR$(129)
9972    INPUT " Enter TEST INDEX file. (1 to 3 alpha-numeric characters) ",Id$
9974    DISP CHR$(128)
9976    !
9978    SELECT LEN(Id$)                                  !Build file prefix
9980    CASE <3
9982      Test_index$=UPC$(Id$)&RPT$("_",3-LEN(Id$))&"_INDEX"
9984    CASE =3
9986      Test_index$=UPC$(Id$)&"_INDEX"
9988    CASE >3
9990      BEEP
9992      GOTO Get_index
9994    END SELECT
9996    !
9998    Read_index(Test_index$,Test_hdrs$(*))
10000   !
10002 Choose_test:                                       !
10004   REPEAT
10006     Test=0
10008     DISP CHR$(129)
10010     INPUT " What test number? (1 =< TEST NUMBER =< 99) ",Test
10012     DISP CHR$(128)
10014     IF Test=0 THEN GOTO Choose_test
10016     Flag=0
10018     Status=0
10020     FOR I=1 TO SIZE(Test_hdrs$,1)
10022       IF Test=VAL(Test_hdrs$(I)[4,5]) THEN
10024         Test_hdr$=Test_hdrs$(I)[1,10]
10026         Flag=1
10028         Status=1
10030       END IF
10032     NEXT I
10034     IF Flag=0 THEN
10036       PRINT TABXY(1,19);"Test No. ";Test;" not available."
10038       BEEP
10040     END IF
10042   UNTIL Flag=1
10044 SUBEND
10046 !___________________________________________________________________
10048 Save_config:SUB Save_config
10050 !
10052 ! This allows the user to save his/her work on disk if an interruption
10054 ! occurs (say, lunch) during an extended analysis session.
10056 ! Actually, what it does is copies all the buffer files to external
```

```
10058 ! files, then writes the names of these files to a "configuration file"
10060 !========================================================================
10062   OPTION BASE 1
10064   COM /Index_string/ Buff_id$(*),Buff_title$(*),Buff_units$(*)
10066   COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
10068   COM /Msus/ Msus_raw1$,Msus_raw2$,Msus_buff$,Msus_ext$,Test_hdr$
10070   !----------------------------------------------------------------------
10072   !
10074   DISP "Copying buffers to external file on ";Msus_ext$;"."
10076   Copy_all(1)
10078   !
10080   REPEAT
10082     INPUT "Enter name of configuration file -",File_config$
10084     IF LEN(File_config$)>10 THEN
10086       DISP "Filename too long - must be 10 characters or less."
10088       WAIT 1.5
10090     END IF
10092   UNTIL File_config$<>"" AND LEN(File_config$)<11
10094   !
10096   File_size=1+INT(1+No_buffers(2)*10/256)
10098   CREATE BDAT File_config$&Msus_ext$,File_size
10100   ASSIGN @Config TO File_config$&Msus_ext$
10102   OUTPUT @Config;Test_hdr$
10104   FOR I=1 TO No_buffers(2)
10106     OUTPUT @Config;Buff_id$(I,2)
10108   NEXT I
10110   !
10112   ASSIGN @Config TO *
10114   DISP "File ";Config$;" created on ";Msus_ext$;"."
10116   WAIT 1.5
10118 SUBEND
10120 !_______________________________________________________________________!
10122 SUB Splice_windows(Id$)
10124 Splice_windows:!
10126   OPTION BASE 1
10128 !-----------------------------------------!
10130 ! This looks for the same channel of data in
10132 ! two different time windows(1 and 2), and
10134 ! splices it together. The data window with
10136 ! the higher sample rate is decimated to the
10138 ! lower sampling rate. This should be used
10140 ! with caution, as aliasing may result.
10142 ! The higher sample rate must be a multiple
10144 ! of the lower.
10146 !-----------------------------------------!
10148   COM /Index_real/ Buff_freq(*),Buff_gain(*),Buff_offset(*),Buff_time(*)
10150   COM /Index_string/ Buff_id$(*),Buff_title$(*),Buff_units$(*)
10152   COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
10154   COM /Index_defaults/ Sample_freq,Events(*)
10156   COM /Raw_defaults/ INTEGER No_avg,Skip,REAL Start_time,Stop_time
10158   COM /Buff_defaults/ Buff_ingain
10160   DIM Fake_events(3)
10162   INTEGER I
10164   Id1$=Id$&"1"
10166   Id2$=Id$&"2"
10168   !---------------------------!
10170   ! Raw files exist?
10172   !---------------------------!
10174   Check_index(1,Id1$,Row1)
10176   Check_index(1,Id2$,Row2)
```

```
10178     IF Row1=0 OR Row2=0 THEN
10180       PRINT "Cannot find one of ";Id$;" windows to splice"
10182       SUBEXIT
10184     END IF
10186     !-----------------------------!
10188     ! Calculate appropriate Skip parameters for each channel
10190     ! ALLOCATE temporary data arrays and load data.
10192     !-----------------------------!
10194     Relskip=Buff_freq(Row1,1)/Buff_freq(Row2,1)
10196     IF Relskip>1 THEN
10198       IF FRACT(Relskip)<>0 THEN
10200         PRINT "Non-multiple sample frequencies- cannot splice ";Id$
10202         SUBEXIT
10204       END IF
10206       Lowskip=INT(1+(Buff_points(Row1,1)/Relskip+Buff_points(Row2,1))/FNSize
10208       PRINT "lowskip,relskip=";Lowskip,Relskip
10210       ALLOCATE Temp1(INT(Buff_points(Row1,1)/(Lowskip*Relskip)))
10212       ALLOCATE Temp2(INT(Buff_points(Row2,1)/(Lowskip)))
10214       Raw_to_temp(Row1,Id1$,Temp1(*),1,Lowskip*Relskip,1,-1)
10216       Raw_to_temp(Row2,Id2$,Temp2(*),1,INT(Lowskip),1,-1)
10218       Sample_freq=Buff_freq(Row2,1)/Lowskip
10220     ELSE
10222       Relskip=1/Relskip
10224       IF FRACT(Relskip)<>0 THEN
10226         PRINT "Non-multiple sample frequencies- cannot splice ";Id$
10228         SUBEXIT
10230       END IF
10232       Lowskip=INT(1+(Buff_points(Row2,1)/Relskip+Buff_points(Row1,1))/FNSize
10234       PRINT "lowskip,relskip=";Lowskip,Relskip
10236       ALLOCATE Temp1(INT(Buff_points(Row1,1)/(Lowskip)))
10238       ALLOCATE Temp2(INT(Buff_points(Row2,1)/(Lowskip*Relskip)))
10240       Raw_to_temp(Row1,Id1$,Temp1(*),1,Lowskip*Relskip,1,-1)
10242       Raw_to_temp(Row2,Id2$,Temp2(*),1,Lowskip,1,-1)
10244       Sample_freq=Buff_freq(Row1,1)/Lowskip
10246     END IF
10248     !-----------------------------!
10250     ! ALLOCATE big array and transfer in the data
10252     !-----------------------------!
10254     ALLOCATE Temp(SIZE(Temp1,1)+SIZE(Temp2,1))
10256     Pts1=SIZE(Temp1,1)
10258     FOR I=1 TO Pts1
10260       Temp(I)=Temp1(I)
10262     NEXT I
10264     FOR I=1+Pts1 TO Pts1+SIZE(Temp2,1)
10266       Temp(I)=Temp2(I-Pts1)
10268     NEXT I
10270     !-----------------------------!
10272     ! OK, store contents of big array as a buffer file.
10274     !-----------------------------!
10276     Fake_events(1)=-999
10278     Fake_events(2)=-999
10280     Fake_events(3)=-999
10282     Temp_to_buff(Temp(*),Id$,Buff_title$(Row1,1),Buff_units$(Row1,1),Sample_
10284     DEALLOCATE Temp(*),Temp2(*),Temp1(*)
10286   SUBEND
10288   !_____________________________________________________________________________!
10290   SUB Statistics(Row,Id$,Index_no)
10292   Statistics:!
10294     OPTION BASE 1
```

```
10296   !------------------------------!
10298   ! This lists the statistics minimum, mean, and maximum for one or more
10300   ! channels on the current printer.
10302   !  INPUTS:   Row - row of Id$ in index, if known (0 if not)
10304   !            Id$ - ID of channel  , or "ALL"
10306   !            Index_no - if Id$="ALL", defines whether raw or buffer
10308   !                          channels are checked.
10310   !                          1 = raw
10312   !                          2 = buffers
10314   !  CALLS :   Get_stats
10316   !------------------------------!
10318   COM /Index_string/ Buff_id$(*),Buff_title$(*),Buff_units$(*)
10320   COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
10322   COM /Hardware/ Prt_address,Current_prt,Computer$
10324   REAL Min,Mean,Max
10326   ASSIGN @Print TO Current_prt
10328                                                    !
10330   OUTPUT @Print;CHR$(132);
10332   OUTPUT @Print USING Stat_header;"Channel";"Minimum";"Mean";"Maximum";CHR
10334                                                    !
10336   IF UPC$(Id$)="ALL" THEN
10338     FOR I=1 TO No_buffers(Index_no)
10340       Row=I
10342       Get_stats(Row,Buff_id$(Row,Index_no),Index_no,Min,Mean,Max)
10344       IF Row<>-1 THEN
10346         OUTPUT @Print USING Stat_image;Buff_id$(Row,Index_no),Min,Mean,Max
10348       END IF
10350     NEXT I
10352   ELSE
10354     Get_stats(Row,Id$,Index_no,Min,Mean,Max)
10356     OUTPUT @Print USING Stat_image;Id$,Min,Mean,Max,Buff_units$(Row,Index_
10358   END IF
10360 Stat_header:IMAGE 9A,3(12A)
10362 Stat_image:IMAGE 9A,3(MD.DDDE,2X),8A
10364 SUBEND
10366 !_______________________________________________________________________
10368 Stress_gauge:SUB Stress_gauge(OPTIONAL Filename$)
10370 !
10372 ! This calculation module calculates the calculated resultant
10374 ! stress from a surface stress gauge. The inputs are in strain
10376 ! units, the output is in stress units. The equation used assumes
10378 ! the angle between the gauges is equal to ARCTAN(poisson's ratio)
10380 ! INPUT (if used) :
10382 ! The filename must consist of the gauge id (without the arm suffix)
10384 ! appended to the time window (1 or 2). See the 2 input prompts below.
10386 !======================================================================
10388   OPTION BASE 1
10390   COM /Accumulators/ No_acc,Size_acc,Acc1(*),Acc2(*),Acc3(*),Acc4(*),Acc5(
10392   COM /Raw_defaults/ INTEGER No_avg,Skip,REAL Start_time,Stop_time
10394   COM /Buff_defaults/ Buff_ingain
10396   !---------------------------------------------------------------------
10398   Poisson=.3                       ! Set Poisson's Ratio
10400   E=5.E+3                          ! Set Young's Modulus
10402   !
10404   IF NPAR=0 OR Filename$="" THEN
10406     INPUT "Enter Stress gauge Id without the arm suffix e.g. 'SS61'",Gauge
10408     Gauge_id$=UPC$(Gauge_id$)
10410     REPEAT
10412       INPUT "Enter the time window desired (1 or 2)",Tw
10414     UNTIL Tw=1 OR Tw=2
```

```
10416   ELSE
10418     Gauge_id$=UPC$(Filename$[1,LEN(Filename$)-1])
10420     Tw=VAL(Filename$[LEN(Filename$)])
10422   END IF
10424   !
10426   Check_index(1,Gauge_id$&"1"&VAL$(Tw),Row)
10428   !
10430   IF Row=0 THEN
10432     PRINT "Cannot find this rosette: ";Gauge_id$
10434     SUBEXIT
10436   END IF
10438   !-----------------------------!
10440   ! Get raw data
10442   !-----------------------------!
10444   Raw_to_acc(0,Gauge_id$&"1"&VAL$(Tw),1,No_avg,Skip,Start_time,Stop_time)
10446   Raw_to_acc(0,Gauge_id$&"2"&VAL$(Tw),2,No_avg,Skip,Start_time,Stop_time)
10448   !-----------------------------!
10450   ! Calculate
10452   !-----------------------------!
10454   MAT Acc3= Acc1+Acc2
10456   MAT Acc3= (.5*E/(1-Poisson))*Acc3
10458   !-----------------------------!
10460   ! Store data in buffer file   !
10462   !-----------------------------!
10464   Acc_to_buff(3,Gauge_id$&"R","Surface Stress","MPa",Buff_ingain,0)
10466 SUBEND
10468 !____________________________________________________________________
10470 Temp_to_acc:SUB Temp_to_acc(Indata(*),Accum_no)
10472 !
10474 ! Puts data from the data array into one of the accumulators.
10476 !====================================================================
10478   OPTION BASE 1
10480   COM /Accumulators/ No_acc,Size_acc,Acc1(*),Acc2(*),Acc3(*),Acc4(*),Acc5(
10482   !-------------------------------------------------------------------
10484   SELECT Accum_no
10486   CASE >No_acc
10488     PRINT "Selected accumulator number not available:";Accum_no
10490     BEEP
10492     SUBEXIT
10494   CASE 1
10496     MAT Acc1= Indata
10498   CASE 2
10500     MAT Acc2= Indata
10502   CASE 3
10504     MAT Acc3= Indata
10506   CASE 4
10508     MAT Acc4= Indata
10510   CASE 5
10512     MAT Acc5= Indata
10514   CASE 6
10516     MAT Acc6= Indata
10518   CASE ELSE
10520     PRINT "Accumulator spec out of range"
10522     BEEP
10524     PRINT "in Acc_to_temp"
10526   END SELECT
10528 SUBEND
10530 !____________________________________________________________________
10532 Temp_to_buff:SUB Temp_to_buff(Buffdata(*),Id$,Title$,Units$,Freq,Replace_f
10534 !
```

```
10536 !  This converts Buffdata to INTEGER by using pre-defined or automatic
10538 !  gain and offset values, and uses it to create a disk data buffer.
10540 !  The index is updated.
10542 !  If Id$ duplicates an existing buffer, the user is asked whether to
10544 !  replace the old buffer with the new one ( Replace_flag can be used
10546 !  to override this - see below)
10548 !
10550 !  INPUTS:
10552 !        Buffdata(*) : Eng. unit data to be put into disk buffer.
10554 !        Id$, Title$, Units$, Sample_freq: as req'd for index.
10556 !        Replace_flag: to determine  whether to replace duplicate buffer.
10558 !                       0 = prompt user to decide.
10560 !                       1 = automatically replace old with new.
10562 !                      -1= do NOT replace duplicate buffer.
10564 !        Data_events(*) is a 3-element array containing:
10566 !                      Data_start -  start of valid data
10568 !                      Data_event - a defined event in middle of data
10570 !                      Data_end    - end of valid data
10572 !
10574 !  IN/OUT:
10576 !        Input_gain,Input_offset:
10578 !           These determine the scaling used for integer storage.
10580 !           If Input_gain=1 then storage is REAL (no conversion)
10582 !           If Input_gain=0  then scaling is set automatically.
10584 !            (for both of above cases, Input_offset is not used.)
10586 !
10588 !  OUTPUT: Buffindex_row: Row of newly-created buffer.
10590 !=========================================================================
10592   OPTION BASE 1
10594   COM /Msus/ Msus_raw1$,Msus_raw2$,Msus_buff$,Msus_ext$,Test_hdr$
10596   COM /Index_string/ Buff_id$(*),Buff_title$(*),Buff_units$(*)
10598   COM /Index_real/ Buff_freq(*),Buff_gain(*),Buff_offset(*),Buff_time(*)
10600   COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
10602   !----------------------------------------------------------------------
10604   REAL Start,Event,End,Gain,Offset,Data_max,Data_min
10606   INTEGER File_size,I,File_purge,Data_pts
10608   DIM File_name$[20],Ans$[5]
10610   !
10612   Data_pts=SIZE(Buffdata,1)
10614   !*
10616   !* Set Autoscale and allocate buffers according to Input_gain
10618   !*
10620   SELECT Input_gain
10622   CASE 0
10624     Auto_range=1
10626     ALLOCATE Tempdata(Data_pts),INTEGER Intdata(Data_pts)
10628   CASE <>1
10630     Auto_range=0
10632     ALLOCATE Tempdata(Data_pts),INTEGER Intdata(Data_pts)
10634   CASE 1
10636     ! no milk today
10638   CASE ELSE
10640     PRINT "Unexpected input_gain= ";Input_gain;"in Temp_to_buff"
10642   END SELECT
10644   !
10646   Id$=UPC$(Id$)                                    !Id$ SHALL be uppercase
10648   !
10650   Start=Data_events(1)
10652   Event=Data_events(2)
10654   End=Data_events(3)
```

```
10656   !
10658   IF No_buffers(2)=50 THEN                      !Max. no buffers= 50
10660     PRINT "BUFFER LIMIT (50?) EXCEEDED. CHANGE CODE."
10662     DISP "BEEP!"
10664     BEEP
10666     STOP
10668   END IF
10670   !*
10672   !* Check Index to see if disk buffer exists
10674   !*
10676   Check_index(2,Id$,Row)
10678   File_purge=0                   !----- Init: NOT ok to replace file.
10680   IF Row>0 THEN                  !----- Duplicate disk buffer found!
10682     SELECT Replace_flag
10684     CASE 0                       !----- Ask user: Replace?
10686       BEEP
10688       OUTPUT KBD;"K";
10690       PRINT TABXY(1,26);"Buffer ";Id$;" exists. "
10692       BEEP
10694       INPUT "Do you want to overwrite it?",Ans$
10696       PRINT TABXY(1,26);"                                   ";
10698       IF UPC$(Ans$[1.1])<>"Y" THEN
10700         SUBEXIT
10702       ELSE
10704         File_purge=1                              !OK to purge old file.
10706       END IF
10708     CASE 1
10710       File_purge=1
10712     CASE -1
10714       SUBEXIT
10716     END SELECT
10718   END IF
10720   !
10722   IF Input_gain<>1 THEN                         !Integerize data and file
10724     DISP "Integerizing data..."
10726     IF Auto_range=1 THEN                        !Auto-set gain and offset
10728       Data_max=MAX(Buffdata(*))
10730       Data_min=MIN(Buffdata(*))
10732       IF Data_max=Data_min THEN
10734         Gain=Data_max/65535
10736       ELSE
10738         Gain=(Data_max-Data_min)/65535
10740       END IF
10742       Offset=32767-Data_max/Gain
10744     ELSE
10746       Gain=Input_gain
10748       Offset=Input_offset
10750     END IF
10752     MAT Tempdata= Buffdata/(Gain)
10754     MAT Intdata= Tempdata+(Offset)
10756     DISP
10758     !
10760 Int_file_create:                              !Create file using ID
10762     ON ERROR GOTO Err_file_create
10764     File_name$=Test_hdr$[1,5]&Id$&Msus_buff$
10766     File_size=.5+INT(Data_pts*2/256)
10768     CREATE BDAT File_name$,File_size
10770     ASSIGN @Buff_file TO File_name$
10772     OFF ERROR
10774     !
```

```
10776 Int_file_write:                                                    !
10778     ON ERROR GOTO Err_file_write
10780     OUTPUT @Buff_file;Intdata(*)
10782     ASSIGN @Buff_file TO *
10784     OFF ERROR
10786   ELSE
10788   !*
10790   !* Store data directly (REAL)
10792   !*
10794 Rea_file_create:                                                   !
10796     ON ERROR GOTO Err_file_create
10798     File_name$=Test_hdr$&Id$&Msus_buff$
10800     File_size=.5+INT(Data_pts*8./256)
10802     CREATE BDAT File_name$,File_size
10804     ASSIGN @Buff_file TO File_name$
10806     OFF ERROR
10808 Rea_file_write:                                                    !
10810     ON ERROR GOTO Err_file_write
10812     OUTPUT @Buff_file;Buffdata(*)
10814     ASSIGN @Buff_file TO *
10816     OFF ERROR
10818     Gain=1
10820     Offset=0
10822   END IF
10824   !
10826   IF Row=0 THEN                                                      !Update index
10828     No_buffers(2)=No_buffers(2)+1
10830     Buffindex_row=No_buffers(2)
10832   ELSE
10834     Buffindex_row=Row
10836   END IF
10838   !
10840   Buff_id$(Buffindex_row,2)=Id$
10842   Buff_title$(Buffindex_row,2)=Title$
10844   Buff_units$(Buffindex_row,2)=Units$
10846   Buff_freq(Buffindex_row,2)=Freq
10848   Buff_gain(Buffindex_row,2)=Gain
10850   Buff_offset(Buffindex_row,2)=Offset
10852   Buff_time(Buffindex_row,2)=Time_offset
10854   Buff_points(Buffindex_row,2)=Data_pts
10856   Buff_start(Buffindex_row,2)=Start
10858   Buff_event(Buffindex_row,2)=Event
10860   Buff_end(Buffindex_row,2)=End
10862   !
10864   PRINT "Disk buffer ";Id$;" created.";
10866   IF Gain=1 THEN
10868     PRINT " (REAL)"
10870   ELSE
10872     PRINT " (INTEGER)"
10874   END IF
10876   !
10878   IF Input_gain<>1 THEN
10880     DEALLOCATE Intdata(*)
10882     DEALLOCATE Tempdata(*)
10884   END IF
10886   SUBEXIT
10888   !++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
10890 Err_file_create:                                                   !
10892   SELECT ERRN
10894   CASE 54
```

```
10896      Ans$=""
10898      IF File_purge=1 THEN
10900        PURGE File_name$
10902        IF Input_gain<>1 THEN
10904          GOTO Int_file_create
10906        ELSE
10908          GOTO Rea_file_create
10910        END IF
10912      END IF
10914      BEEP
10916      INPUT "TURF OLD FILE?",Ans$
10918      IF UPC$(Ans$[1,1])="Y" THEN
10920        PURGE File_name$
10922        IF Input_gain<>1 THEN
10924          GOTO Int_file_create
10926        ELSE
10928          GOTO Rea_file_create
10930        END IF
10932      END IF
10934    CASE ELSE
10936      PRINT ERRM$
10938      PAUSE
10940    END SELECT
10942    IF Input_gain<>1 THEN
10944      DEALLOCATE Intdata(*)
10946      DEALLOCATE Tempdata(*)
10948    END IF
10950    SUBEXIT
10952    !
10954 Err_file_write:                                      !
10956    PRINT ERRM$
10958    IF Input_gain<>1 THEN
10960      DEALLOCATE Intdata(*)
10962      DEALLOCATE Tempdata(*)
10964    END IF
10966 SUBEND
10968 !_____________________________________________________________________
10970 !
10972 Wait_for_key:SUB Wait_for_key
10974 !
10976 ! Wait for user to press a key, then restore the screen to normal.
10978 !=====================================================================
10980   OPTION BASE 1
10982   COM /Hardware/ Prt_address,Current_prt,Computer$
10984   !-------------------------------------------------------------------
10986   ENTER KBD;Ans$
10988   CONTROL 1,12;2
10990   CONTROL 1,10;1
10992 SUBEND
10994 !_____________________________________________________________________
10996 !
10998 Write_stats:SUB Write_stats(Index_no,Filename$,OPTIONAL Flag)
11000 !
11002 ! This writes the statistics min, mean, and max of either raw or
11004 !        buffer files to a data file.
11006 ! INPUTS: Index_no = 1 : raw files
11008 !                  = 2 : buffer files
11010 !          Filename$    : output filename (appends Msus_raw2$)
11012 !               Flag    : if 1, auto purges old stats file of same name.
11014 !                       : if 0 (default) , asks before purging.
```

```
11016 ! File format is: Channel_id$, Min, Mean, Max  (last 3 REAL)
11018 !  CALLS: Get_stats
11020 !======================================================================
11022   OPTION BASE 1
11024   COM /Index_string/ Buff_id$(*),Buff_title$(*),Buff_units$(*)
11026   COM /Index_real/ Buff_freq(*),Buff_gain(*),Buff_offset(*),Buff_time(*)
11028   COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
11030   COM /Msus/ Msus_raw1$,Msus_raw2$,Msus_buff$,Msus_ext$,Test_hdr$
11032   COM /Raw_defaults/ INTEGER No_avg,Skip,REAL Start_time,Stop_time
11034   !---------------------------------------------------------------------
11036   IF NPAR=3 THEN
11038     Flg=Flag
11040   ELSE
11042     Flg=0
11044   END IF
11046   !----------------------------!
11048   Filesize=INT(.5+No_buffers(Index_no)*(50)/256)
11050   ON ERROR GOTO File_exist
11052 File_create:  !
11054   CREATE BDAT Filename$&Msus_raw2$,Filesize
11056   OFF ERROR
11058   ASSIGN @File TO Filename$&Msus_raw2$
11060   OUTPUT @File;Start_time;Stop_time
11062   FOR I=1 TO No_buffers(Index_no)
11064     Row=I
11066     Get_stats(Row,Buff_id$(Row,Index_no),Index_no,Min,Mean,Max)
11068     IF Row<>-1 THEN
11070       OUTPUT @File;Buff_id$(Row,Index_no);Min;Mean;Max;Buff_units$(Row,Ind
11072     END IF
11074   NEXT I
11076   ASSIGN @File TO *
11078   SUBEXIT
11080 File_exist:  !
11082   OFF ERROR
11084   IF ERRN=54 THEN
11086     IF Flg>0 THEN
11088       PURGE Filename$&Msus_raw2$
11090     ELSE
11092       REPEAT
11094         DISP "Purge old statistics file: ";Filename$;"?";
11096         INPUT Ans$
11098         Ans$=UPC$(Ans$[1,1])
11100       UNTIL Ans$="Y" OR Ans$="N"
11102       IF Ans$="Y" THEN
11104         PURGE Filename$&Msus_raw2$
11106         GOTO File_create
11108       ELSE
11110         SUBEXIT
11112       END IF
11114     END IF
11116   ELSE
11118     PRINT ERRM$
11120   END IF
11122   GOTO File_create
11124   !
11126 SUBEND
11128 !_____________________________________________________________________!
11130 DEF FNYesno(Ans$)
11132   IF UPC$(Ans$[1,1])="Y" THEN
11134     RETURN 1
```

```
11136   ELSE
11138     RETURN 0
11140   END IF
11142 FNEND
11144 !______________________________________________________________________________!
11146 DEF FNSize_ascii(@File)
11148   STATUS @File,5;Recs
11150   STATUS @File,6;Bytes
11152   RETURN (Recs-1)*256+Bytes-1
11154 FNEND
11156 !***************************************************************
11158 SUB Create_ascii
11160   OPTION BASE 1
11162 Create_ascii:!
11164 !-----------------------------
11166 ! Writes an ASCII output file from the first four raw buffers.
11168 ! If less than 4 buffers are available, writes less.
11170 ! User prompted for filename.
11172 !------------------------------
11174   COM /Index_string/ Buff_id$(*),Buff_title$(*),Buff_units$(*)
11176   COM /Index_points/ REAL No_buffers(*),Buff_points(*),Buff_start(*),Buff_
11178   COM /Msus/ Msus_raw1$,Msus_raw2$,Msus_buff$,Msus_ext$,Test_hdr$
11180   COM /Accumulators/ No_acc,Acc_size,Acc1(*),Acc2(*),Acc3(*),Acc4(*),Acc5(
11182!-----------------------------------------------------------------------
11184   DIM File_name$[10],Header$[82]
11186   INTEGER No_channels,Samples,Ch,I
11188   !
11190   PRINT "Creating an ASCII file"
11192   INPUT "Enter name of ASCII file",File_name$
11194!
11196   No_channels=MIN(4,No_buffers(1))
11198!
11200   Samples=Acc_size
11202   FOR Ch=1 TO No_channels
11204     Samples=MIN(Samples,Buff_points(Ch,1))
11206   NEXT Ch
11208   PRINT "OK, no. channels, samples=",No_channels,Samples
11210!
11212   Header$="This is a test."
11214!---------------------------------------
11216! Create big data buffer to hold the data !
11218!---------------------------------------
11220   ALLOCATE All_data(Samples,No_channels)
11222!****************
11224! Parameters in CALL:
11226!Raw_to_acc(Row,Id$,Acc_no,INTEGER No_avg,Skip,REAL Start_time,Stop_time)
11228!****************
11230   FOR Ch=1 TO No_channels
11232     PRINT "Channel ",Ch,": ",Buff_id$(Ch,1)
11234     CALL Raw_to_acc(0,Buff_id$(Ch,1),1,1,1,0,-1)! Raw to Acc1
11236!
11238     FOR I=1 TO Samples                ! Acc1 to All_data
11240       All_data(I,Ch)=Acc1(I)
11242     NEXT I
11244!
11246   NEXT Ch
11248!
11250   CALL Write_ascii(All_data(*),Header$,File_name$)
11252   PRINT "Is it done?"
11254 SUBEND
```

```
11256 !______________________________________________________________________
11258 SUB Write_ascii(Eng_data(*),Header$,File_name$)
11260 Write_ascii:!
11262   OPTION BASE 1
11264   COM /Msus/ Msus_raw1$,Msus_raw2$,Msus_buff$,Msus_ext$,Test_hdr$
11266   INTEGER I,J,Blocks,Blocksize
11268   !-----------------------------------------------!
11270   !
11272   ! Writes ASCII data file.
11274   ! Header$ is first line in file.
11276   ! Eng_data(Samples, No_channels) is array of REAL.
11278   !
11280   !-----------------------------------------------!
11282   ALLOCATE Outbuff$[82]
11284   Samples=SIZE(Eng_data,1)
11286   No_channels=SIZE(Eng_data,2)
11288   !
11290   !---------------------!
11292   ! Create ASCII file.
11294   !---------------------!
11296   ON ERROR GOTO File_error
11298   !
11300   ! (no_chan * no_samples/chan) * (80 bytes/7 samples) / 256 bytes/record
11302   File_size=INT(.5+(Samples*100/256))
11304   PRINT "Creating "&File_name$&Msus_ext$,File_size
11306   !
11308 Create_file:  !
11310   CREATE ASCII File_name$&Msus_ext$,File_size
11312   GOTO File_ready
11314 File_error:!
11316   IF ERRN=54 THEN
11318     BEEP
11320     PRINT "Duplicate file name: ",File_name$
11322     INPUT "Okay to destroy old version?",Ans$
11324     IF FNYesno(Ans$) THEN
11326       PURGE File_name$&Msus_ext$
11328       GOTO Create_file
11330     ELSE
11332       STOP
11334     END IF
11336   ELSE
11338     PRINT ERRM$
11340     BEEP
11342     STOP
11344   END IF
11346   PRINT "Unexplained error line 12600"
11348   STOP
11350 File_ready:  !
11352   OFF ERROR
11354   ASSIGN @Outfile TO File_name$&Msus_ext$
11356   ASSIGN @Crt TO CRT
11358   PRINT "No. bytes before writing:";FNSize_ascii(@Outfile)
11360   !---------------------!
11362   ! Line 1: Header       !
11364   !---------------------!
11366 L1out:IMAGE #,79A
11368   PRINT "writing header$",Header$
11370   OUTPUT Outbuff$ USING L1out;Header$
11372   OUTPUT @Outfile;Outbuff$;
11374   OUTPUT @Crt;Outbuff$
```

```
11376   !
11378   !----------------------!
11380   ! Actual data transfer !
11382   !----------------------!
11384   ALLOCATE Databuff$[20],Bigbuff$[82]
11386   FOR I=1 TO Samples
11388     Databuff$=""
11390     FOR J=1 TO No_channels
11392       OUTPUT Databuff$ USING Outimage;Eng_data(I,J)
11394       Bigbuff$[(J-1)*20+1]=Databuff$
11396     NEXT J
11398     Bigbuff$[(No_channels*20+1)]=RPT$(" ",(4-No_channels)*20)
11400     OUTPUT @Outfile;Bigbuff$;
11402     OUTPUT @Crt;Bigbuff$;
11404   NEXT I
11406     !
11408 Outimage:IMAGE $,MD.DDDESZZ,10X
11410   ASSIGN @Outfile TO *
11412             !
11414   GOTO File_over
11416 File_over:  !
11418   DEALLOCATE Databuff$
11420   SUBEXIT
11422 SUBEND
11424 !__________________________________________________________________________
11426 !
11428 Check_plotter:SUB Check_plotter
11430 !
11432 !==========================================================================
11434   OPTION BASE 1
11436   !
11438   Addr$=SYSTEM$("PLOTTER IS")
11440 Plotter_ready:                                           !
11442   SELECT VAL(Addr$)
11444   CASE 1,3,6                                             !PRT, CRT
11446     SUBEXIT
11448   CASE 705                                               !HPIB
11450     ASSIGN @Addr TO VAL(Addr$)
11452     OUTPUT @Addr;"OI"
11454     ENTER @Addr;Type$
11456     SELECT Type$                                         !What plotter?
11458     CASE "7470A"
11460       GOSUB Check
11462     CASE "7475A"
11464       GOSUB Check
11466     CASE ELSE
11468       PRINT "ERROR in Check_plotter: unknown plotter type."
11470       PAUSE
11472     END SELECT
11474     ASSIGN @Addr TO *
11476   CASE ELSE
11478     PRINT "ERROR in Check_plotter: unknown plotter address."
11480     PAUSE
11482   END SELECT
11484   SUBEXIT
11486   !++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
11488 Check:                                                   !
11490   OUTPUT @Addr;"OS"
11492   ENTER @Addr;Status
11494   SELECT Status
```

```
11496   CASE 0,8,40
11498     PRINT "Check for paper installed, etc."
11500     DISP CHR$(129)
11502     INPUT " Plotter ready? (Press ENTER or RETURN to continue) ",Wait$
11504     DISP CHR$(128)
11506     GOTO Plotter_ready
11508   CASE 16,24
11510     OUTPUT @Addr;"IN,OE"
11512     ENTER @Addr;Errors
11514     IF Errors<>0 THEN
11516       PRINT "PLOTTER ERROR in Check_plotter = ";Errors
11518       PAUSE
11520     END IF
11522   CASE ELSE
11524     PRINT "STATUS ERROR in Check_plotter = ";Status
11526     PAUSE
11528   END SELECT
11530   RETURN
11532 SUBEND
11534 !_______________________________________________________________________
11536 Act_load:SUB Act_load(OPTIONAL File_name$)
11538 !
11540 ! Calculates the individual actuator (ram) loads using the differential
11542 ! actuator pressures. It then sums the individual actuator loads to get
11544 ! the total applied load. The resultant data is stored in buffers.
11546 !======================================================================
11548   OPTION BASE 1
11550   COM /Accumulators/ No_acc,Size_acc,Acc1(*),Acc2(*),Acc3(*),Acc4(*),Acc5(
11552   COM /Raw_defaults/ INTEGER No_avg,Skip,REAL Start_time,Stop_time
11554   COM /Buff_defaults/ Buff_ingain
11556   !---------------------------------------------------------------------
11558   ALLOCATE Xdcr_id$(2)[5]
11560   !
11562   No_act=3
11564   FOR Act=1 TO No_act                                 !Get Eng. data
11566     Xdcr_id$(1)="1APE"&VAL$(Act)
11568     Xdcr_id$(2)="1APR"&VAL$(Act)
11570     Raw_to_acc(0,Xdcr_id$(1),1,No_avg,Skip,Start_time,Stop_time)
11572     Raw_to_acc(0,Xdcr_id$(2),2,No_avg,Skip,Start_time,Stop_time)
11574     !
11576     MAT Acc1= Acc1*(.1338)                            !MN = MPa*area (in M^2)
11578     MAT Acc2= Acc2*(.0752)                            !\Load = load(extend)
11580     MAT Acc3= Acc1-Acc2                               !/       - load(retract)
11582     IF SIZE(Acc4,1)<>SIZE(Acc1,1) THEN
11584       REDIM Acc4(SIZE(Acc1,1))
11586     END IF
11588     MAT Acc4= Acc4+Acc3                               !Sum loads for total
11590     !
11592     New_id$="1AL"&VAL$(Act)                           !Save Act Load in buffer
11594     Title$="Actuator "&VAL$(Act)&" Load"
11596     Acc_to_buff(3,New_id$,Title$,"MN",Buff_ingain,0)
11598   NEXT Act
11600   !
11602   New_id$="1ALT"                                      !Save Total Load in buffer
11604   Title$="Total Load"
11606   Acc_to_buff(4,New_id$,Title$,"MN",Buff_ingain,0)
11608 SUBEND
```

```
11650 Calc_fft:SUB Calc_fft(OPTIONAL File_name$)
11652 !       .
11654 ! Does an Fast Fourier Transform on a selected engineered-data file.
11656 !=======================================================================
11658   OPTION BASE 1
11660   COM /Accumulators/ No_acc,Size_acc,Acc1(*),Acc2(*),Acc3(*),Acc4(*),Acc5(
11662   COM /Raw_defaults/ INTEGER No_avg,Skip,REAL Start_time,Stop_time
11664   COM /Calc_modules/ Module_index$(150,3)[30],First_calc,No_calcs
11666   COM /Responses/ Response_id$[20],Ch_id$[20]
11668   COM /Msus/ Msus_raw1$,Msus_raw2$,Msus_buff$,Msus_ext$,Test_hdr$
11670   COM /Index_defaults/ Sample_freq,Events(3)
11672   COM /Graph_stuff/ Color(6),Line(6),Overlay_no,Full_screen,Split_format,A
11674   !----------------------------------------------------------------------
11676   DIM X(4096),Y(4096),R(4096)
11678   INTEGER Flag
11680   REAL Row
11682   !
11684 Start:                                            !Get eng'd data
11686   Time_1=Start_time
11688   Time_2=Stop_time
11690   Keys_off
11692   Ask_for_channel(1,"Enter raw data file to be FFT'd.",Ch_id$,Flag,Row)
11694   !
11696 Plot_data:                                        !Plot eng'd/windowed data
11698   Acc_no=1
11700   Raw_to_acc(Row,Ch_id$,Acc_no,No_avg,Skip,Start_sample,Stop_sample)
11702   Freq=FNSample_freq(Row,1)/MAX(No_avg,Skip)
11704   !
11706   Plot_no=0                                       ! Full screen
11708   Exec_module(Ch_id$,Flag,Row)
11710   SELECT Flag
11712   CASE 1
11714     Keys_off
11716     Plot_raw(Plot_no,Row,Ch_id$,No_avg,Skip,Time_1,Time_2)
11718     IF Row<>-1 THEN
11720       Auto_dump=0
11722       GOSUB Post_plot
11724     END IF
11726   CASE ELSE                                       ! Oops
11728     PRINT "Nothing to plot."
11730   END SELECT
11732   !
11734 Start_fft:                                        !Window/FFT plot routine
11736   INPUT "Window eng'd data (0), Do FFT (1), New channel (2), Abort (3)",Fn
11738   SELECT Fn
11740   CASE 0                                          ! Window data
11742     PRINT TABXY(1,19);"Origanal start time =";Start_time
11744     PRINT "Origanal stop time =";Stop_time
11746     INPUT "Enter new start time.",Time_1
11748     INPUT "Enter new stop time.",Time_2
11750     GOTO Plot_data
11752   CASE 1                                          ! FFT data
11754     PRINT "Building windowed array for FFT routine."
11756     First=INT(Time_1/Stop_time*SIZE(Acc1,1))+1
11758     Last=INT(Time_2/Stop_time*SIZE(Acc1,1))
11760   CASE 2
11762     GOTO Start
11764   CASE 3                                          ! Abort FFT routine
11766     SUBEXIT
```

```
11768   CASE ELSE                                                     ! Oops
11770     GOTO Start_fft
11772   END SELECT
11774   !
11776   Keys_off                                                      !Build FFT data arrays
11778   J=0
11780   FOR I=First TO Last
11782     J=J+1
11784     X(J)=I-1
11786     Y(J)=Accl(I)
11788   NEXT I
11790   REDIM X(J-1),Y(J-1)
11792   !
11794   Setup_fft(Y(*),R(*),X(*),Freq)                                !Perform FFT operation
11796   !
11798 Replot:                                                         !Plot FFT
11800   Keys_off
11802   Ymin=MIN(R(*))
11804   Ymax=MAX(R(*))
11806   Xmin=MIN(X(*))
11808   Xmax=MAX(X(*))
11810   ALLOCATE Ylbl$[10],Xlbl$[10],Rt_title$[30],Lt_title$[30]
11812   Lt_title$="FFT of "&Ch_id$
11814   Rt_title$="Series "&Test_hdr$[1,3]&" Test "&Test_hdr$[4,5]
11816   Ylbl$="!A'Z!"
11818   Xlbl$="Freq (Hz)"
11820   Message1$=""
11822   Message2$=""
11824   Auto=1
11826   Auto_dump=0
11828   Plot_pos=0
11830   Plot_set(Plot_pos)
11832   Keys_off
11834   Plot_label(Xmin,Xmax,Ymin,Ymax,Lt_title$,Rt_title$,Xlbl$,Ylbl$,0,0,Messa
11836   Plot_xy(R(*),X(*),Color(1),Line(1),"")
11838   DEALLOCATE Ylbl$,Xlbl$,Rt_title$,Lt_title$
11840   GOSUB Post_plot
11842   Keys_on
11844   !
11846 Retry:                                                          !
11848   Ans$=""
11850   INPUT "Replot FFT? (Y/N)",Ans$
11852   SELECT UPC$(Ans$[1])
11854   CASE "N"
11856     SUBEXIT
11858   CASE "Y"
11860     GOTO Replot
11862   CASE ELSE
11864     GOTO Retry
11866   END SELECT
11868   SUBEXIT
11870   !++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
11872 Post_plot:                                                      !After plot subroutine
11874   SELECT Auto_dump
11876   CASE 0                                                        ! Wait for key
11878     BEEP
11880     Wait_for_key
11882   CASE 1                                                        ! Dump to printer
11884     ON TIMEOUT 7,1 GOTO Dump_timeout
11886     DUMP GRAPHICS
```

```
11888   GOTO Done_dump
11890 Dump_timeout:PRINT "Cannot dump plot; printer timeout!"
11892 Done_dump:               !
11894   OFF TIMEOUT 7
11896  CASE -1                 ! Replot with ext. plotter
11898 Replot_ext:              !
11900   INPUT "Is Plotter ready to plot?",Ans$
11902   IF UPC$(Ans$[1,1])="Y" THEN
11904     ON TIMEOUT 7,1 RECOVER No_plotter
11906     OUTPUT 705;"OS"
11908     OFF TIMEOUT
11910     Chg_plotter("705")
11912     Auto_dump=0          !Temporarily disable
11914     Seq2$(1)=Sequence$(I) !before
11916     Auto_seq(Seq2$(*))   !Recursive call to send to
11918     DISP                 !plotter
11920   END IF
11922   Auto_dump=-1
11924 Done_plot:               !
11926   Chg_plotter("CRT")
11928  END SELECT
11930  ALPHA ON
11932  GRAPHICS OFF
11934  RETURN
11936  !
11938 No_plotter:              !Missing plotter
11940  Clear_screen
11942  BEEP
11944  WAIT .1
11946  BEEP
11948  INPUT "I cannot find the plotter anywhere. Have you seen it?",Ans$
11950  IF UPC$(Ans$[1,1])="Y" THEN
11952    GOTO Replot_ext
11954  ELSE
11956    GOSUB Auto_disable
11958    GOTO Done_plot
11960  END IF
11962 SUBEND
11964 !____________________________________
11966 Setup_fft:SUB Setup_fft(A(*),R(*),X(*),Sample_freq)
11968 !
11970 ! A is input (data), R is output (amplitude), X is output (frequency)
11972 !====================================
11974  OPTION BASE 1
11976  DIM B(4096),J(4096)
11978  INTEGER Op,Inorder,Outorder,Power
11980  !
11982  RAD
11984  Inorder=SIZE(A,1)
11986  Power=1+INT(LOG(Inorder-1)/LOG(2))
11988  Outorder=2^Power
11990  PRINT Inorder,Outorder,Power
11992  REDIM B(Outorder),R(Outorder/2),J(Outorder/2),X(Outorder/2)
11994  !
11996  MAT B= (0)
11998  Init=INT((Outorder-Inorder)/2)
12000  FOR I=1 TO Inorder
12002    B(I+Init)=A(I)
12004  NEXT I
12006  !
```

```
12005   FOR I=1 TO Outorder/2
12010     R(I)=B(2*I-1)
12012     J(I)=B(2*I)
12014     X(I)=I-1
12016   NEXT I
12018   !
12020   Xmax=Outorder/2-1                                   !Build freq array
12022   Freq_conv=Sample_freq/(2*Xmax)
12024   MAT X= X*(Freq_conv)
12026   !
12028   Op=1                                                !Calculate FFT / IFFT
12030   Fft_calc(R(*),J(*),Op,Outorder/2,Power)
12032   J(1)=0
12034   MAT R= R . R
12036   MAT J= J . J
12038   MAT R= R+J
12040   MAT R= R/(SIZE(R,1))
12042 SUBEND
12044 !______________________________________________________________________
12046 Fft_calc:SUB Fft_calc(R_(*),I_(*),INTEGER Flg,N,Power)
12048 !
12050 ! HP canned FFT routine. Some cosmetic/structural changes made.
12052 !======================================================================
12054   Baddata=(N<=0) OR (Flg<>1) AND (Fig<>-1) OR (Power<=0)
12056   WHILE Baddata<>0
12058     PRINT FNLin$(2);"ERROR IN SUBPROGRAM Fft."
12060     PRINT "N=";N,"Flg=";Flg,"Power=";Power;FNLin$(2)
12062     PAUSE
12064   END WHILE
12066   IF Fig=-1 THEN Ifft
12068   !
12070 Fft:K=0                                             !FFT routine
12072   FOR J=1 TO N-1
12074     I=2
12076     WHILE K>=N/I
12078       K=K-N/I
12080       I=I+I
12082     END WHILE
12084     K=K+N/I
12086     IF K>J THEN
12088       A=R_(J+1)
12090       R_(J+1)=R_(K+1)
12092       R_(K+1)=A
12094       A=I_(J+1)
12096       I_(J+1)=I_(K+1)
12098       I_(K+1)=A
12100     END IF
12102   NEXT J
12104   G=.5
12106   P=1
12108   FOR I=1 TO Power-1
12110     G=G+G
12112     C=1
12114     E=0
12116     Q=SQR((1-P)/2)*Flg
12118     P=(1-2*(I=1))*SQR((1+P)/2)
12120     FOR R=1 TO G
12122       FOR J=R TO N STEP G+G
12124         K=J+G
12126         A=C*R_(K)+E*I_(K)
```

```
12128          B=E*R_(K)-C*I_(K)
12130          R_(K)=R_(J)-A
12132          I_(K)=I_(J)+B
12134          R_(J)=R_(J)+A
12136          I_(J)=I_(J)-B
12138        NEXT J
12140        A=E*P+C*Q
12142        C=C*P-E*Q
12144        E=A
12146      NEXT R
12148    NEXT I
12150    IF Flg=-1 THEN SUBEXIT
12152      !
12154 Ifft:A=PI/N                                        !Inverse FFT routine
12156    P=COS(A)
12158    Q=Flg*SIN(A)
12160    A=R_(1)
12162    R_(1)=A+I_(1)
12164    I_(1)=A-I_(1)
12166    IF Flg<>-1 THEN
12168      R_(1)=R_(1)/2
12170      I_(1)=I_(1)/2
12172    END IF
12174    C=Flg
12176    E=0
12178    FOR J=2 TO N/2
12180      A=E*P+C*Q
12182      C=C*P-E*Q
12184      E=A
12186      K=N-J+2
12188      A=R_(J)+R_(K)
12190      B=(I_(J)+I_(K))*C-(R_(J)-R_(K))*E
12192      U=I_(J)-I_(K)
12194      V=(I_(J)+I_(K))*E+(R_(J)-R_(K))*C
12196      R_(J)=(A+B)/2
12198      I_(J)=(U-V)/2
12200      R_(K)=(A-B)/2
12202      I_(K)=-(U+V)/2
12204    NEXT J
12206    !
12208    I_(N/2+1)=-I_(N/2+1)
12210    IF Flg=-1 THEN Fft
12212    !
12214    FOR J=1 TO N
12216      R_(J)=R_(J)/N
12218      I_(J)=I_(J)/N
12220    NEXT J
12222 SUBEND
```

APPENDIX A.5

Calibration Data on Blade Pressure Cells

```
DESIGN OF SURFACE SENSORS            FILE "SURFACE1"    may 05 1988

CALCULATIONS TAKING INTO ACCOUNT AIR ,LOAD TAKEN BY EDGE
UNIFORM ICE LOAD CASE               KIG BLADE DESIGN

INPUT PARAMETERS FOR KIGORIAK BLADE DESIGN
----------------------------------------------
YOUNGS MODULUS STEEL      E           2.10E+11 (Pa)
POISSONS RATIO BRASS      NU          3.31E-01
PLATE THICKNESS           t           2.54E-03 (m)
PLATE RADIUS              a           3.81E-02 (m)


INTERNAL VOLUME           v           6.50E-06 (m^3)
FRACTION AIR IN OIL       GAMMA       1.00E-04
FILL PRESSURE             q_0         2.00E+05 (Pa)
MERCURY BULK MODULUS      k           2.50E+11 (Pa)

CALCULATED INTERMEDIATE VARIABLES
----------------------------------------------
16*E*T^3*V/PI*(1-NU^2)*A^6            4.18E+07
                       A              1.67E-04
                       B              4.18E+03


OUTPUT QUANTITIES
----------------------------------------------
ICE PRESSURE       FLUID PRESSURE     BENDING STRESS     PLATE DEFLECTION
   (Pa)               (Pa)                (Pa)                (m)
5.00E+03           4.90E+03            1.70E+04            4.36E-07
1.00E+04           9.80E+03            3.33E+04            4.36E-07
1.00E+05           9.86E+04            2.36E+05            4.35E-07
5.00E+05           4.97E+05            5.17E+05            4.39E-07
1.00E+06           9.96E+05            6.16E+05            4.46E-07
5.00E+06           5.00E+06            8.20E+05            5.14E-07
1.00E+07           9.99E+06            9.74E+05            5.99E-07
2.00E+07           2.00E+07            1.26E+06            7.70E-07
3.00E+07           3.00E+07            1.55E+06            9.41E-07
4.00E+07           4.00E+07            1.83E+06            1.11E-06
5.00E+07           5.00E+07            2.11E+06            1.28E-06
6.00E+07           6.00E+07            2.40E+06            1.45E-06
8.00E+07           8.00E+07            2.96E+06            1.80E-06
9.00E+07           9.00E+07            3.24E+06            1.97E-06
1.00E+08           1.00E+08            3.53E+06            2.14E-06
```

APPENDIX A.6

Blade Test Data Plots

6.0 BLADE TEST DATA PLOTS

Two sets of tests are presented in this section, calibration tests and actual blade tests. Tests number PBC series are calibration tests and PBT1 to PBT19 are propeller blade tests. The data were collected using "PROP_DAS" and the plots generated by "PROP_PLOT".

```
Description: PROJECT 9448: PROP BUSTERS TESTS - THE REAL THING
--------------------------------------------------------------
PBT01_HDR      14:33:29     6 May 1988      OK
PBT02_HDR      11:34:37    10 May 1988      OK
PBT03_HDR      13:56:43    10 May 1988      OK
PBT04_HDR      14:59:13    10 May 1988      OK
PBT05_HDR      11:46:59    11 May 1988      OK
PBT06_HDR      13:55:42    11 May 1988      OK
PBT07_HDR      11:56:56    12 May 1988      OK
PBT08_HDR      11:21:16    16 May 1988      OK
PBT09_HDR      09:31:53    17 May 1988      OK
PBT10_HDR      11:53:01    17 May 1988      OK
PBT11_HDR      15:24:12    17 May 1988      OK
PBT12_HDR      15:11:37    18 May 1988      OK
PBT13_HDR      11:50:56    19 May 1988      NG *
PBT14_HDR      13:48:34    19 May 1988      OK
PBT15_HDR      15:01:56    19 May 1988      OK
PBT16_HDR      11:32:17    20 May 1988      OK
PBT17_HDR      11:50:14    20 May 1988      OK
PBT18_HDR      12:20:08    20 May 1988      OK
PBT19_HDR      14:31:17    20 May 1988      OK
--------------------------------------------------------------
```

GEOTECHnical resources ltd
PROP BUSTERS
PROJECT NUMBER: 9448

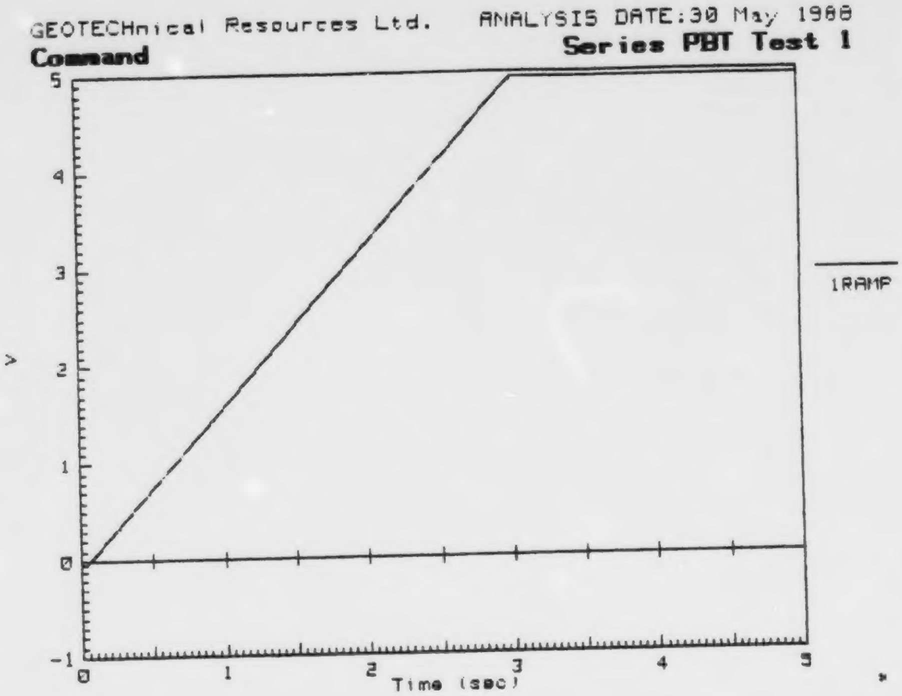
```
Date:  6 May 1988
Time: 14:29:04

Test series...... PBT
Test number...... 1

*** Window 1 ***
Test duration .................. 5 Second(s)
AD-200 sample period............ 15.6 Micro-second(s)
Sample rate, aggregate ......... 64102 Hz.
Sample rate per channel ........ 4006 Hz.
Number of samples per channel .. 20034 words.
Total number of samples ........ 641088 words.
Trigger source ................. INTERNAL
Number of cards ................ 2
Number of channels per card .... 16
Total number of channels ....... 32
```

```
Transducer table for test #PBT01_HDR

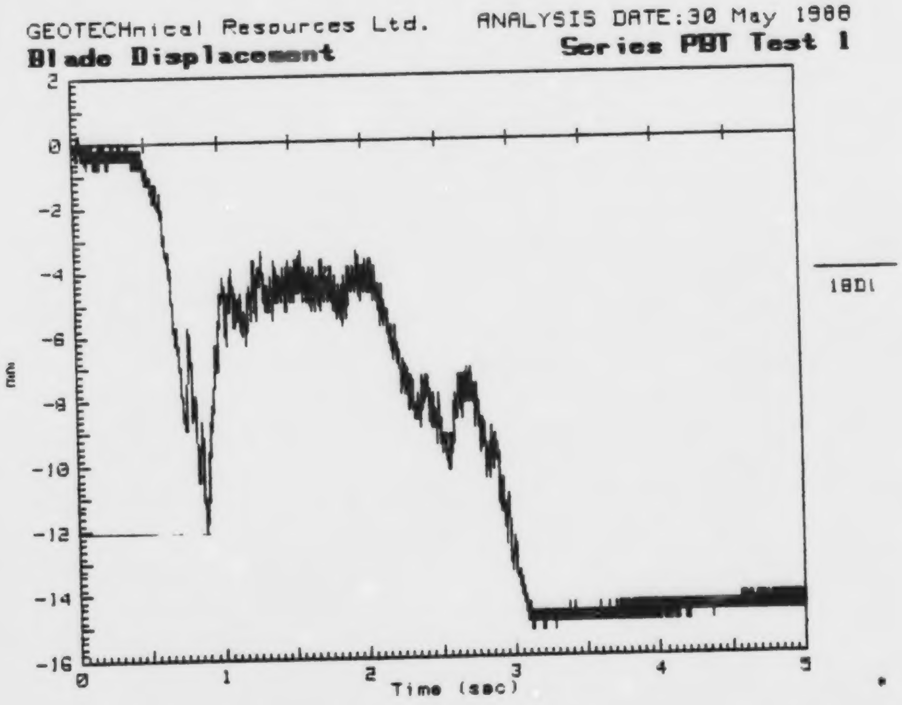
14730 Card1:!
14740    !-----|--|--|--|--|----|--------|--------|-------|------|---------|
14750    !Card |Ch!SW!HW!Ex!Mode|  Gain  | Offset | Units |  Ch  |  Serial |
14760    ! no. |no!gn!gn!gn!    | (eng/V)|  (V)   | (/V)  |  Id  |  Number |
14770    !-----|--|--|--|--|----|--------|--------|-------|------|---------|
14780    DATA 1, 1, 1, 1, 1, "S",  53.643,  2.8613,   "mm", "BD1",  "A33380"
14790    DATA 1, 2, 1, 1, 1, "S",  53.711,  2.8955,   "mm", "BD2",  "A22090"
14800    DATA 1, 3, 1, 1, 1, "S",  53.711,  2.4292,   "mm", "BD3",  "A22091"
14810    DATA 1, 4, 1, 1, 1, "S",  6.8529,  0.0879,  "MPa","APR1",    "5817"
14820    DATA 1, 5, 1, 1, 1, "S",  6.8586,  0.0049,  "MPa","APE1",    "4986"
14830    DATA 1, 6, 1, 1, 1, "S",  6.8792,  0.0562,  "MPa","APR2",    "5723"
14840    DATA 1, 7, 1, 1, 1, "S",  6.8636,  0.0708,  "MPa","APE2",    "5815"
14850    DATA 1, 8, 1, 1, 1, "S",  6.8643,  0.0806,  "MPa","APR3",    "5883"
14860    DATA 1, 9, 1, 1, 1, "S",  6.8531,  0.0562,  "MPa","APE3",    "5885"
14870    DATA 1,10, 1, 1, 1, "S",  13.709,  0.0830,  "MPa", "BP1",    "5887"
14880    DATA 1,11, 1, 1, 1, "S",  13.712,  0.0757,  "MPa", "BP2",    "5773"
14890    DATA 1,12, 1, 1, 1, "S",  13.734,  0.0903,  "MPa", "BP3",    "5892"
14900    DATA 1,13, 1, 1, 1, "S",  13.731,  0.0098,  "MPa", "BP4",    "5889"
14910    DATA 1,14, 1, 1, 1, "S",  13.717,  0.0000,  "MPa", "BP5",    "5891"
14920    DATA 1,15, 1, 1, 2, "S",     1.0,       0,  "  V","RAMP",  "      "
14930    DATA 1,16, 1, 1, 1, "S",  1000.0,       0,   "uE","BR1B",  "      "
14940 Card2:!
14950    DATA 2, 1 ,1, 1, 2, "S",  53.906,  1.3965,   "mm", "AD1",  "A22091"
14960    DATA 2, 2, 1, 1, 2, "S",  53.634,  1.3623,   "mm", "AD2",  "A33381"
14970    DATA 2, 3, 1, 1, 2, "S",  53.608,  1.5918,   "mm", "AD3",  "A33382"
14980    DATA 2, 4, 1, 1, 1, "S",  1000.0,       0,   "uE","FSG1",  "      "
14990    DATA 2, 5, 1, 1, 1, "S",  1000.0,       0,   "uE","FSG2",  "      "
15000    DATA 2, 6, 1, 1, 1, "S",  1000.0,       0,   "uE","FSG3",  "      "
15010    DATA 2, 7, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS7",  "      "
15020    DATA 2, 8, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS8",  "      "
15030    DATA 2, 9, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS9",  "      "
15040    DATA 2,10, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS1",  "      "
15050    DATA 2,11, 1, 1, 1, "S",  1000.0,       0,   "uE","BR2B",  "      "
15060    DATA 2,12, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS3",  "      "
15070    DATA 2,13, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS4",  "      "
15080    DATA 2,14, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS5",  "      "
15090    DATA 2,15, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS6",  "      "
15100    DATA 2,16, 1, 1, 1, "S",  1000.0,       0,   "uE","FSB2",  "      "
15110    !-----|--|--|--|--|----|--------|--------|-------|------|---------|
15120    !Card |Ch!SW!HW!Ex!Mode|  Gain  | Offset | Units |  Ch  |  Serial |
15130    ! no. |no!gn!gn!gn!    | (Eng/V)|  (V)   | (/V)  |  Id  |  Number |
15140    !-----|--|--|--|--|----|--------|--------|-------|------|---------|
15150 End_transducers:!
```



GEOTECHnical Resources Ltd. ANALYSIS DATE:30 May 1988

Command

Series PBT Test 1



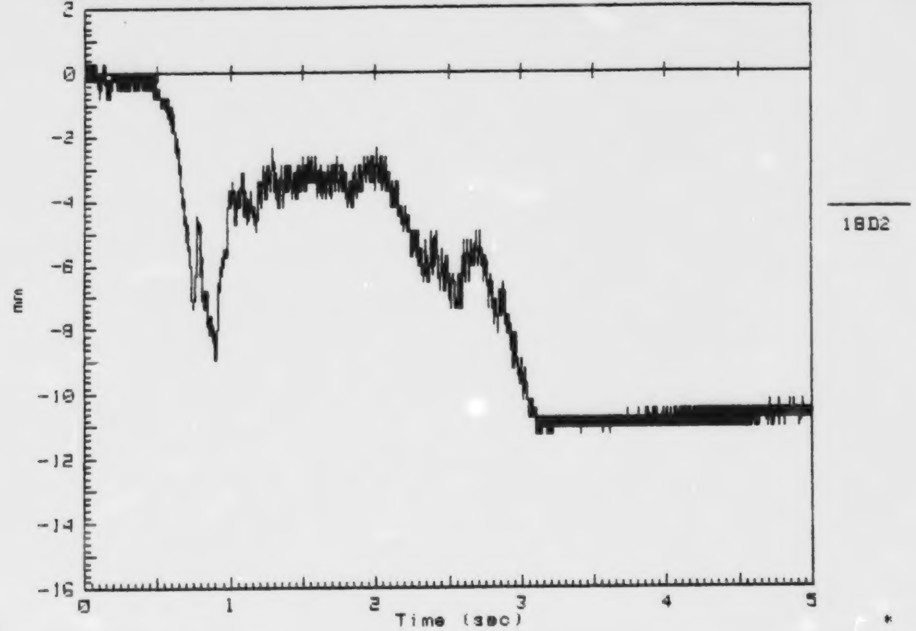
GEOTECHnical Resources Ltd. ANALYSIS DATE:30 May 1988

Blade Displacement

Series PBT Test 1

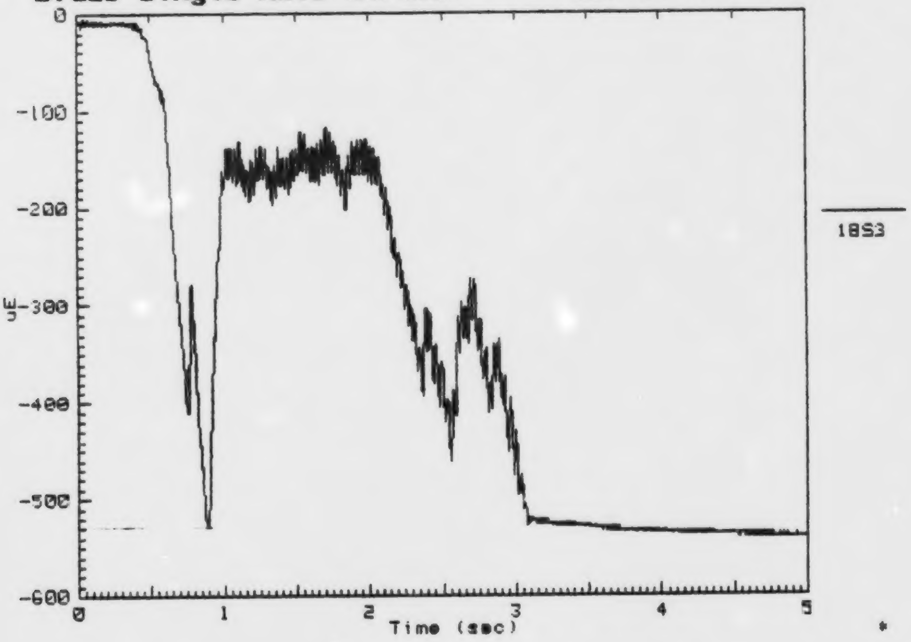
GEOTECHnical Resources Ltd. ANALYSIS DATE:30 May 1988

Blade Displacement **Series PBT Test 1**



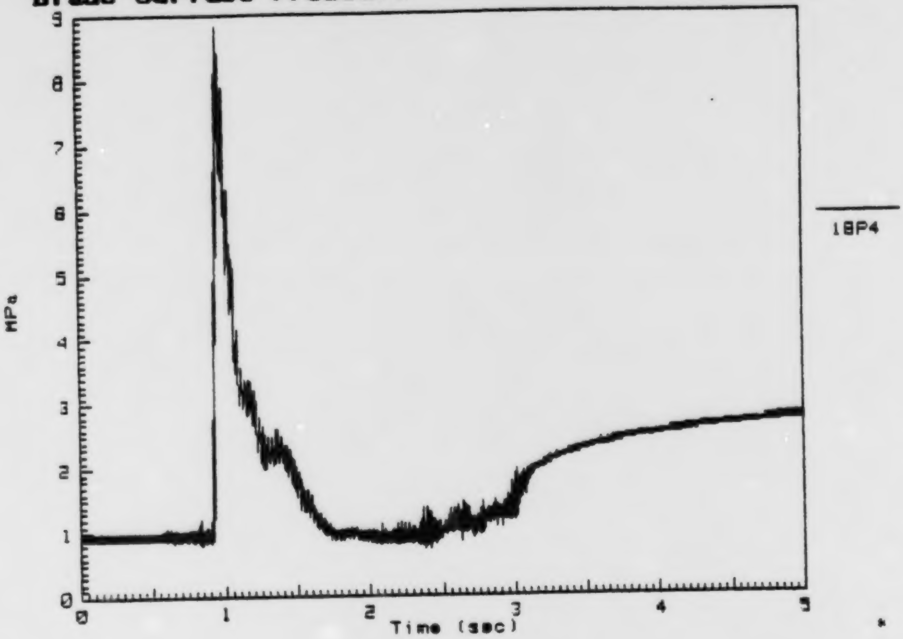
GEOTECHnical Resources Ltd. ANALYSIS DATE:30 May 1988

Blade Single-Axis Strain **Series PBT Test 1**



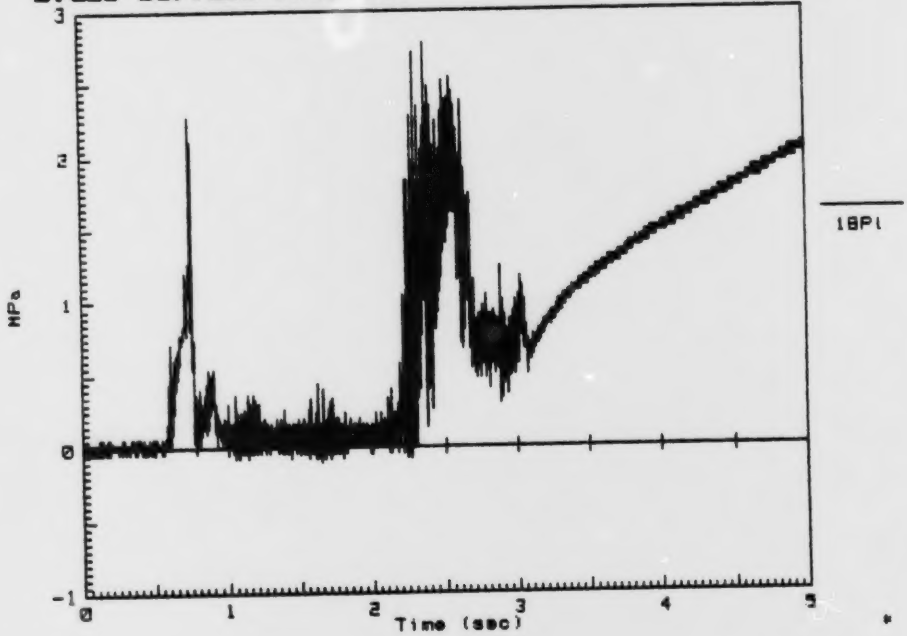
GEOTECHnical Resources Ltd. ANALYSIS DATE: 6 May 1988

Blade Surface Pressure **Series PBT Test 1**



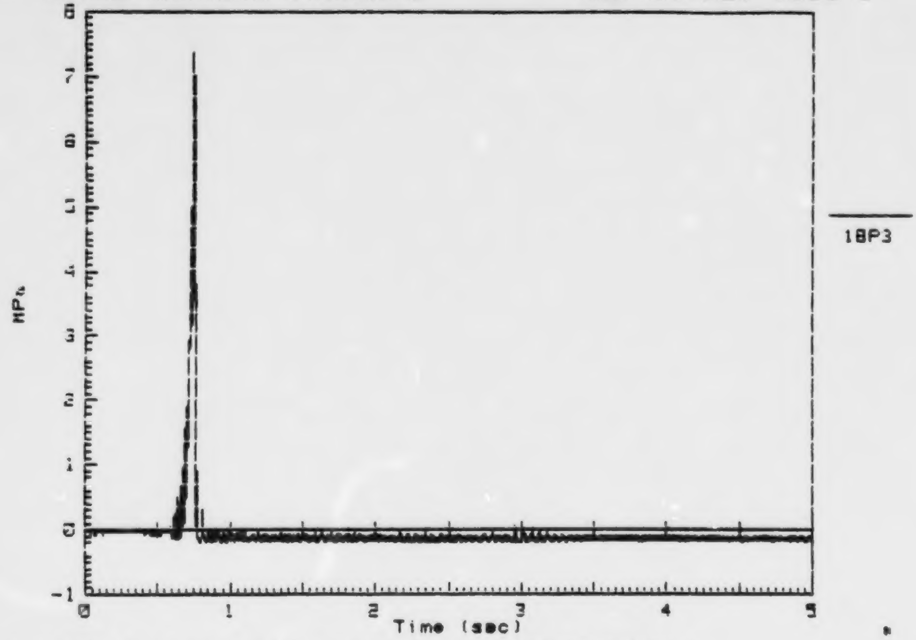
GEOTECHnical Resources Ltd. ANALYSIS DATE: 6 May 1988

Blade Surface Pressure **Series PBT Test 1**



GEOTECHnical Resources Ltd. ANALYSIS DATE: 6 May 1988

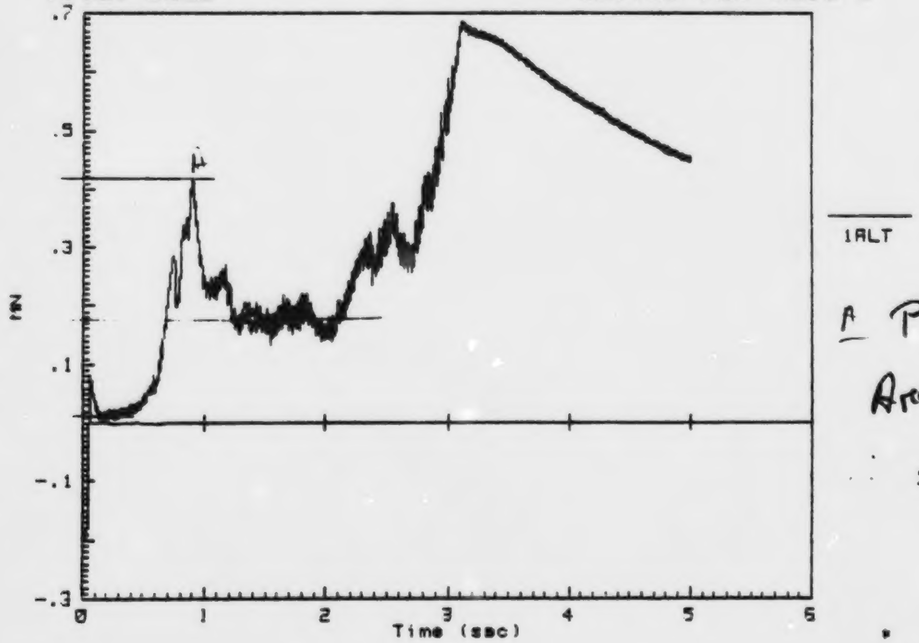
Blade Surface Pressure **Series PBT Test 1**



```
in buff_to_temo, buff_gain(*) =  1.37052891391E-5
```

GEOTECHnical Resources Ltd. ANALYSIS DATE: 6 May 1988

Total Load **Series PBT Test 1**



A peak load ≈ 0.4 MPa

Area ≈ ~1 m²

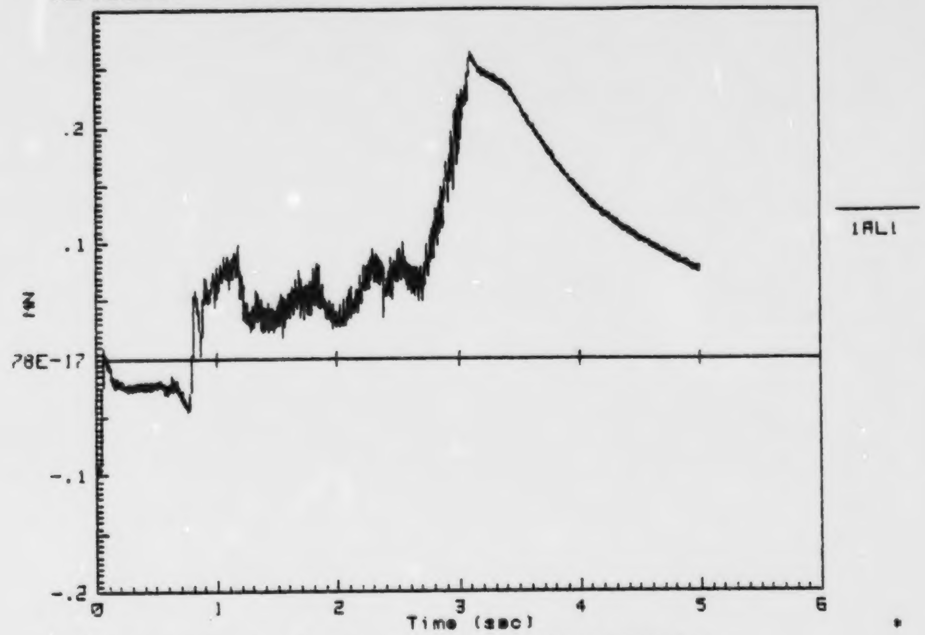
∴ strength ≈ 0.4 MPa

[illegible] load ≈ 1 MN

```
in buff_to_temp, buff_gain(*) =  5.54575346189E-6
```

GEOTECHnical Resources Ltd.   ANALYSIS DATE: 6 May 1988

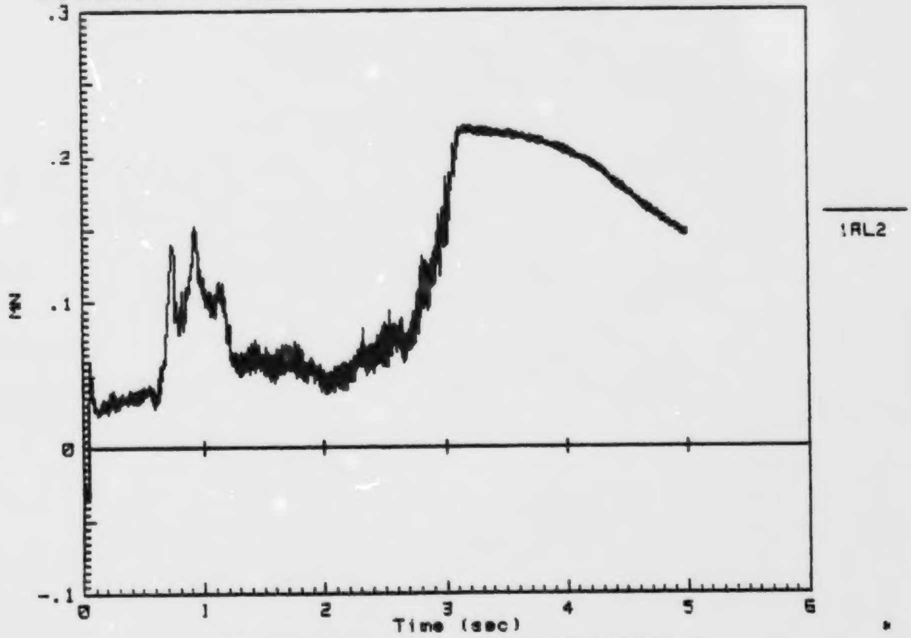
Actuator 1 Load **Series PBT Test 1**



```
in buff_to_temp, buff_gain(*) =  4.14453365806E-6
```

GEOTECHnical Resources Ltd.   ANALYSIS DATE: 6 May 1988

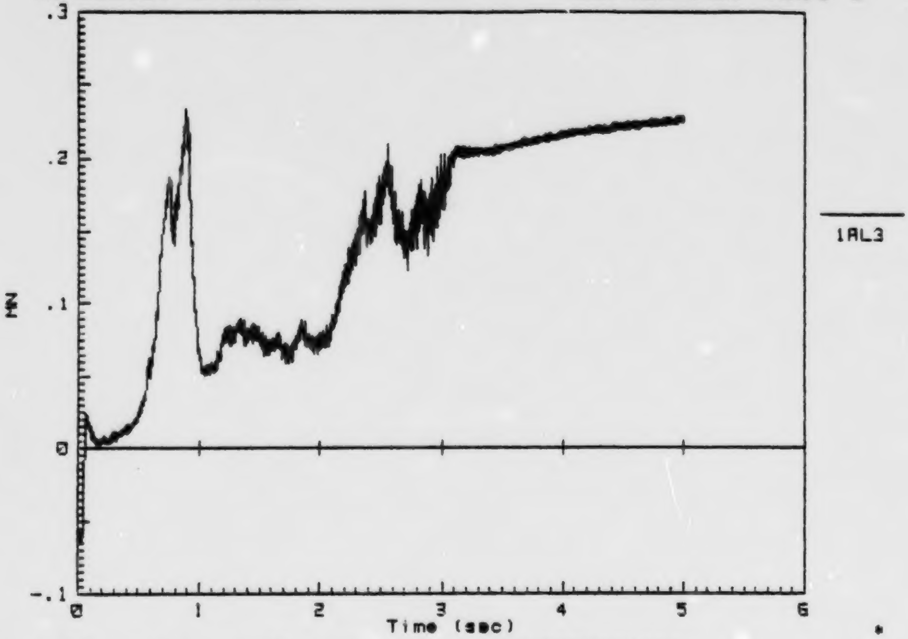
Actuator 2 Load **Series PBT Test 1**



```
in buff_to_temp, buff_gain(*) =  4.68159525251E-6
```

GEOTECHnical Resources Ltd. ANALYSIS DATE: 6 May 1988

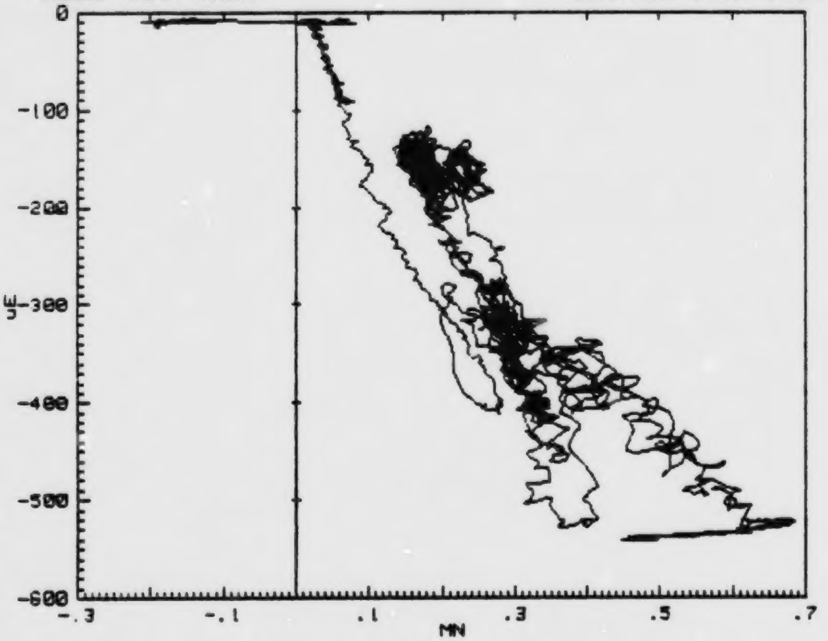
Actuator 3 Load **Series PBT Test 1**



```
in buff_to_temp, buff_gain(*) =  .00815851024262
in buff_to_temp, buff_gain(*) =  1.37052891391E-5
```

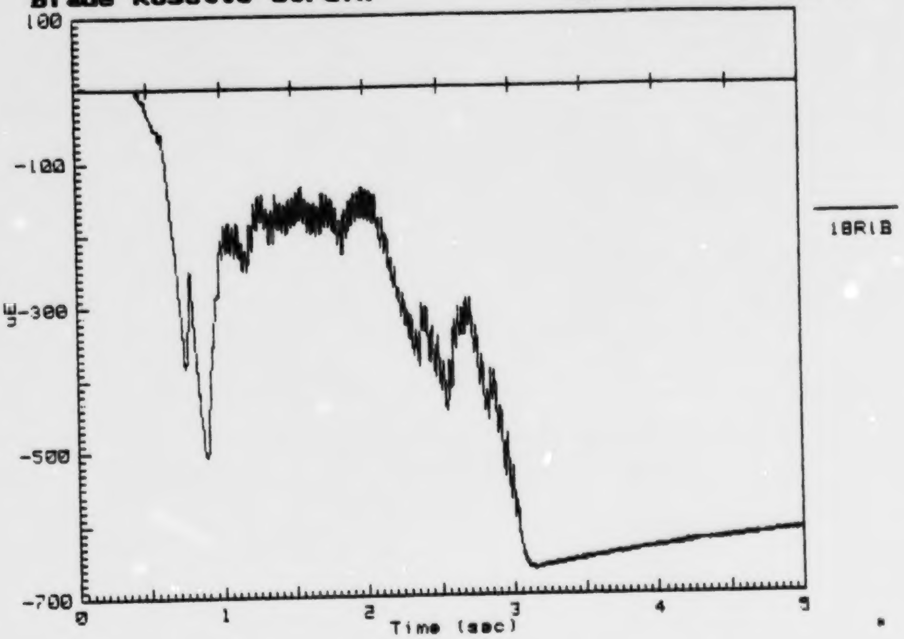
GEOTECHnical Resources Ltd. ANALYSIS DATE: 6 May 1988

1BS3 vs. 1ALT **Series PBT Test 1**



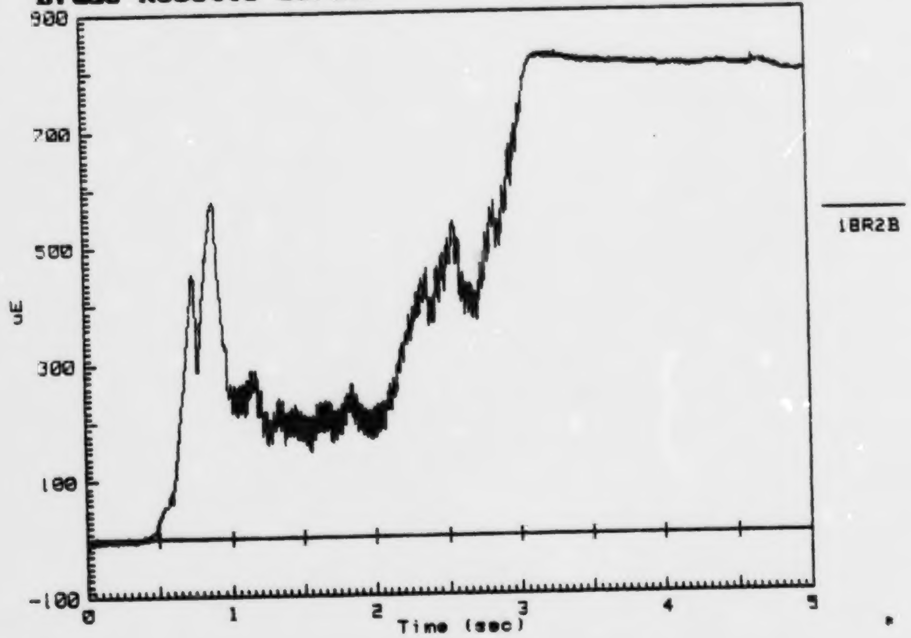
GEOTECHnical Resources Ltd. ANALYSIS DATE: 6 May 1988

Blade Rosette Strain **Series PBT Test 1**



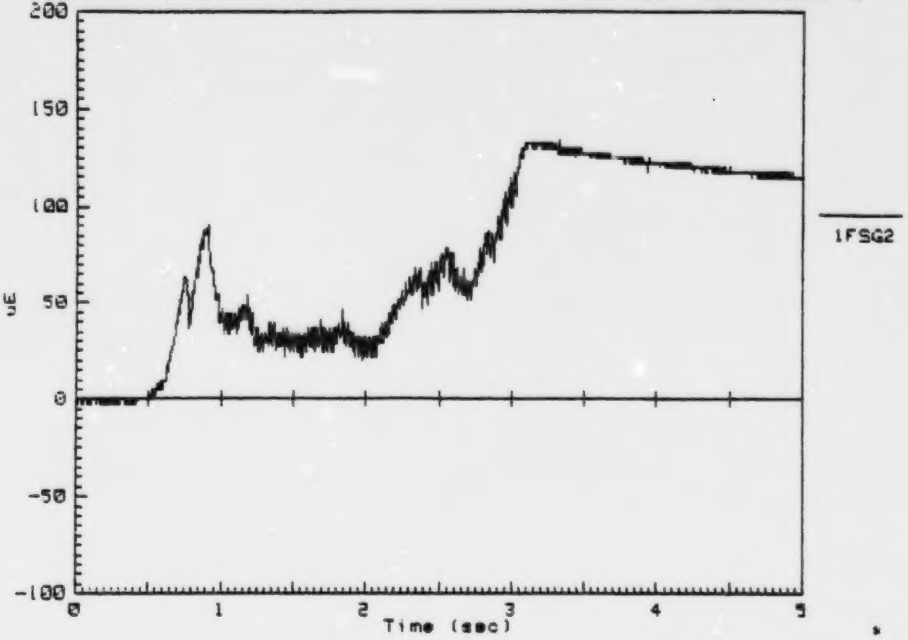
GEOTECHnical Resources Ltd. ANALYSIS DATE: 6 May 1988

Blade Rosette Strain **Series PBT Test 1**



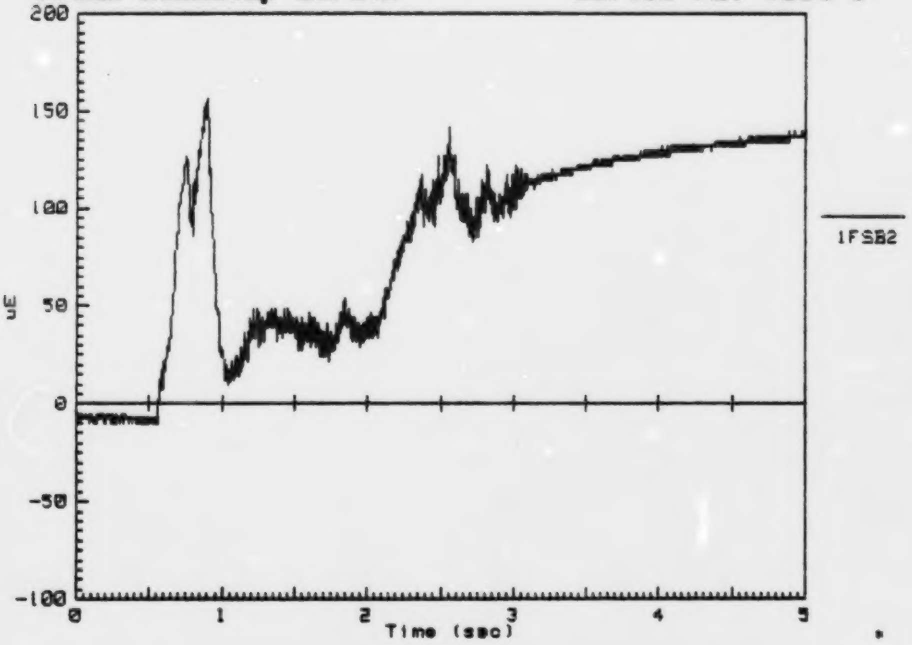
GEOTECHnical Resources Ltd. ANALYSIS DATE: 6 May 1988

Frame Girder Strain **Series PBT Test 1**



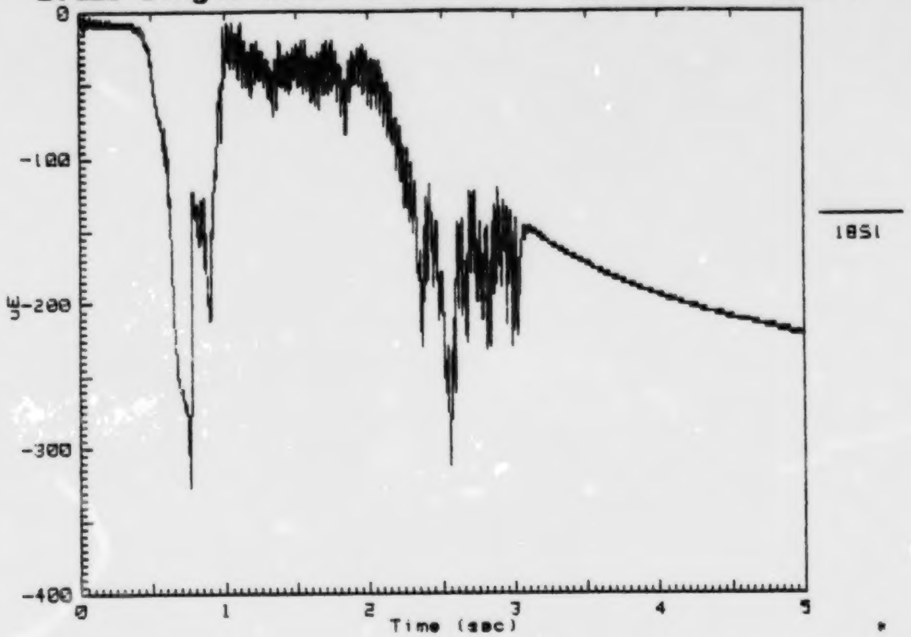
GEOTECHnical Resources Ltd. ANALYSIS DATE: 6 May 1988

Frame Backstop Strain **Series PBT Test 1**



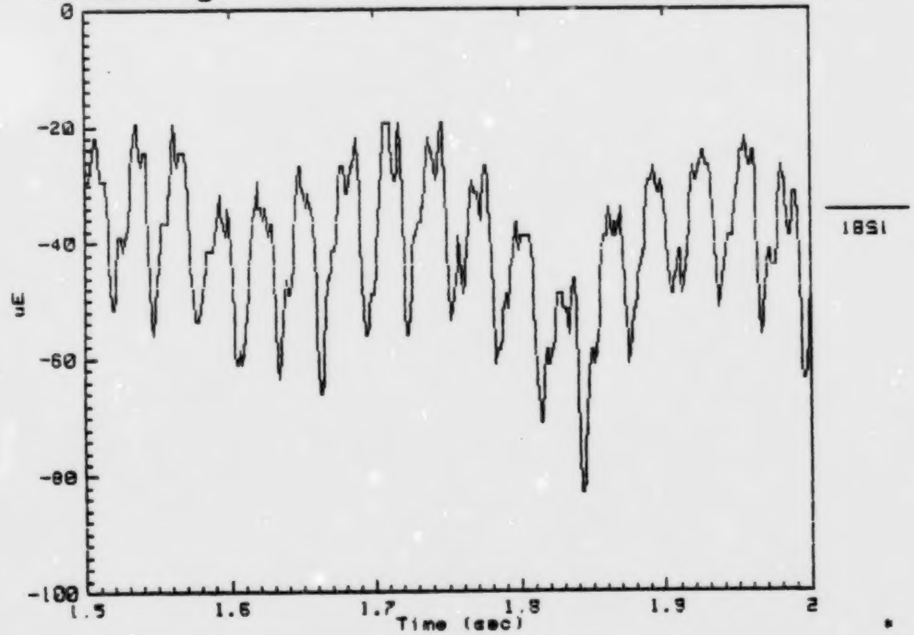
GEOTECHnical Resources Ltd. ANALYSIS DATE: 6 May 1988

Blade Single-Axis Strain **Series PBT Test 1**



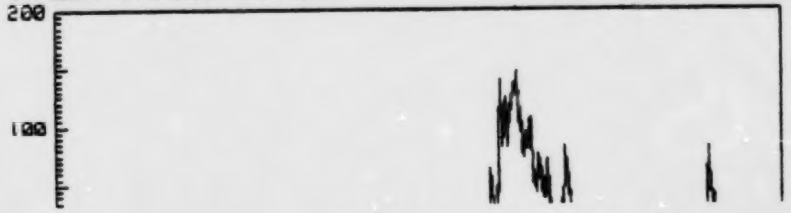
GEOTECHnical Resources Ltd. ANALYSIS DATE: 6 May 1988

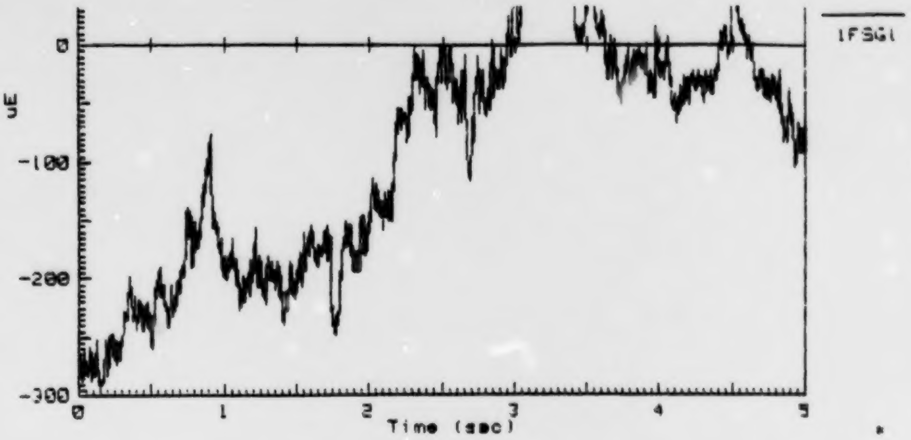
Blade Single-Axis Strain **Series PBT Test 1**



GEOTECHnical Resources Ltd. ANALYSIS DATE: 6 May 1988

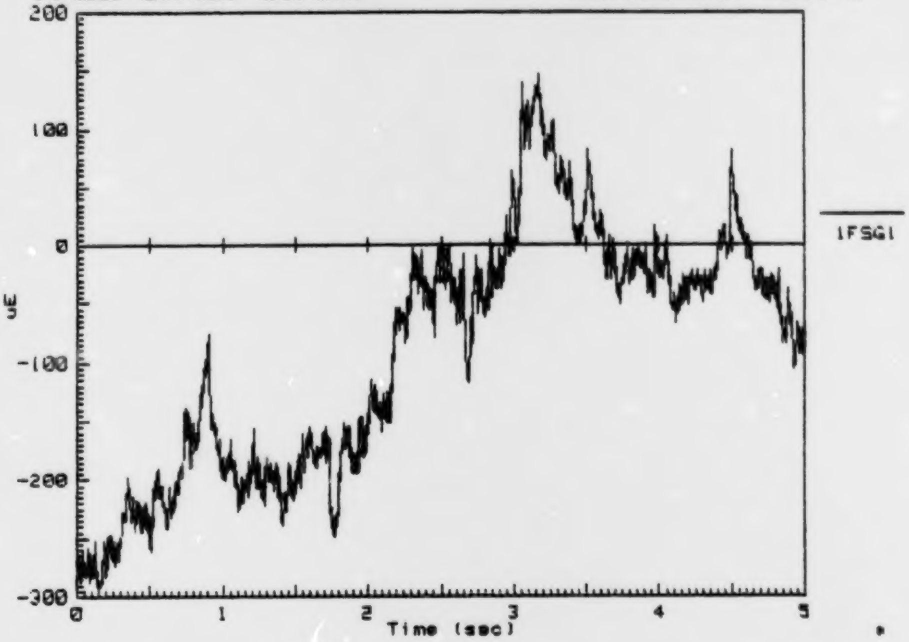
Frame Girder Strain **Series PBT Test 1**





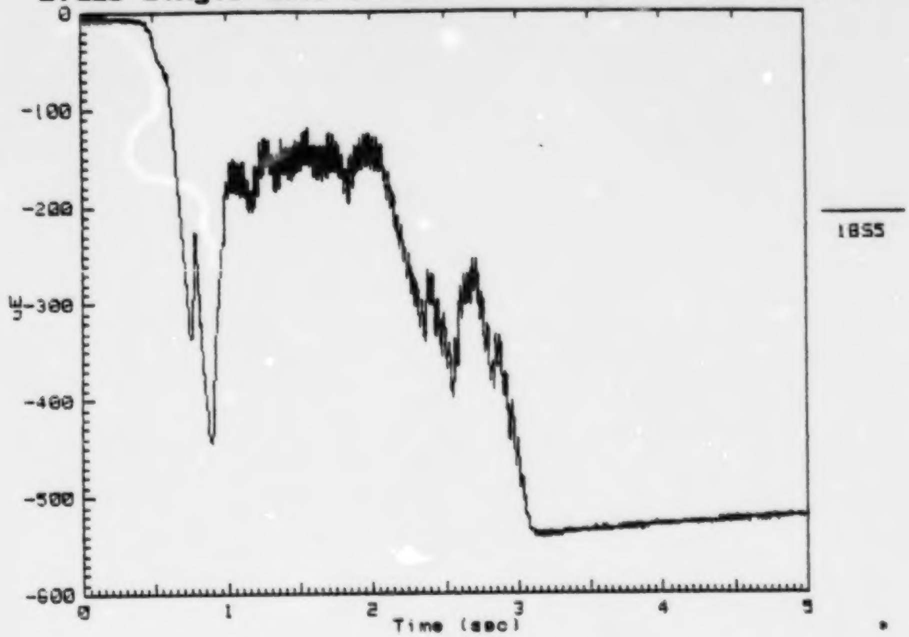
GEOTECHnical Resources Ltd.   ANALYSIS DATE: 6 May 1988

Frame Girder Strain **Series PBT Test 1**



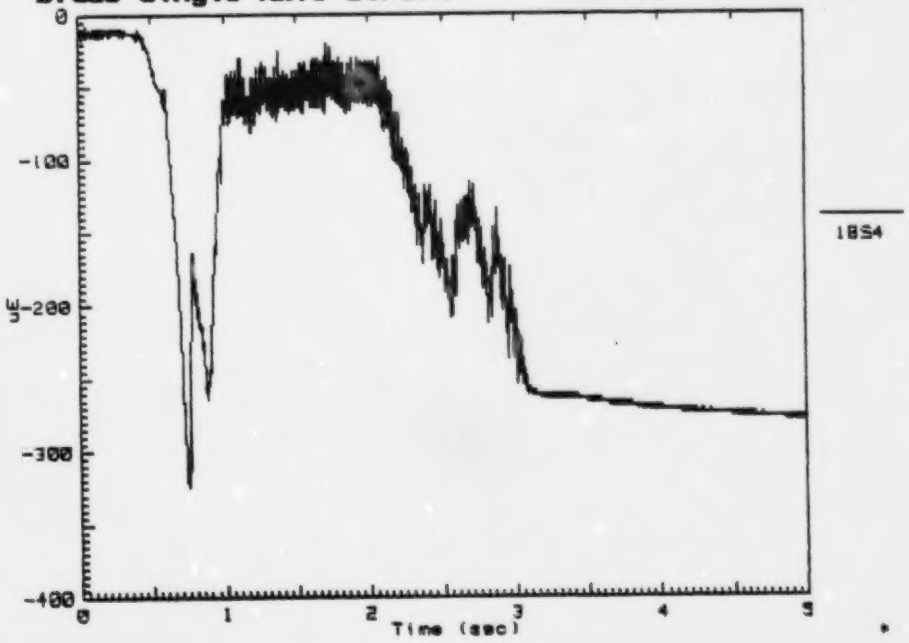
GEOTECHnical Resources Ltd. ANALYSIS DATE: 6 May 1988

Blade Single-Axis Strain **Series PBT Test 1**



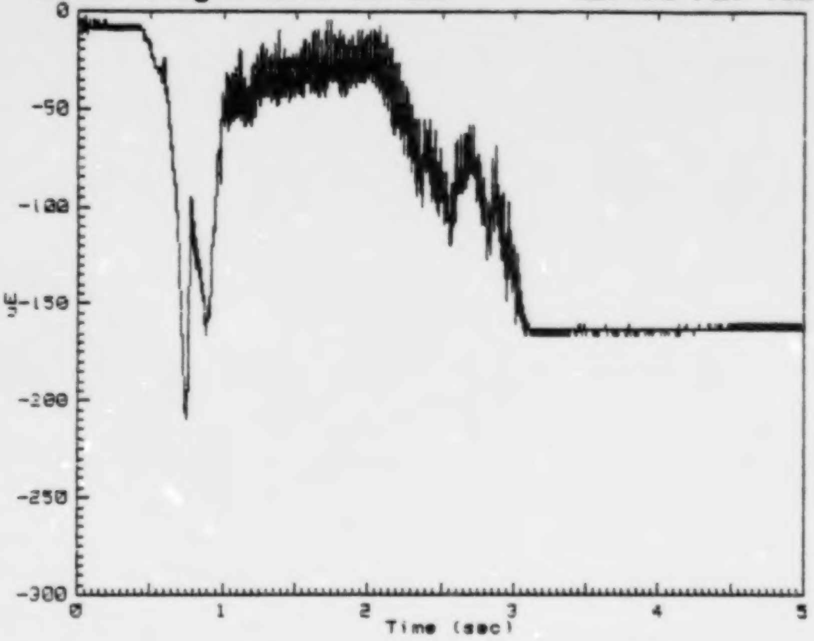
GEOTECHnical Resources Ltd. ANALYSIS DATE: 6 May 1988

Blade Single-Axis Strain **Series PBT Test 1**



GEOTECHnical Resources Ltd. ANALYSIS DATE: 6 May 1988

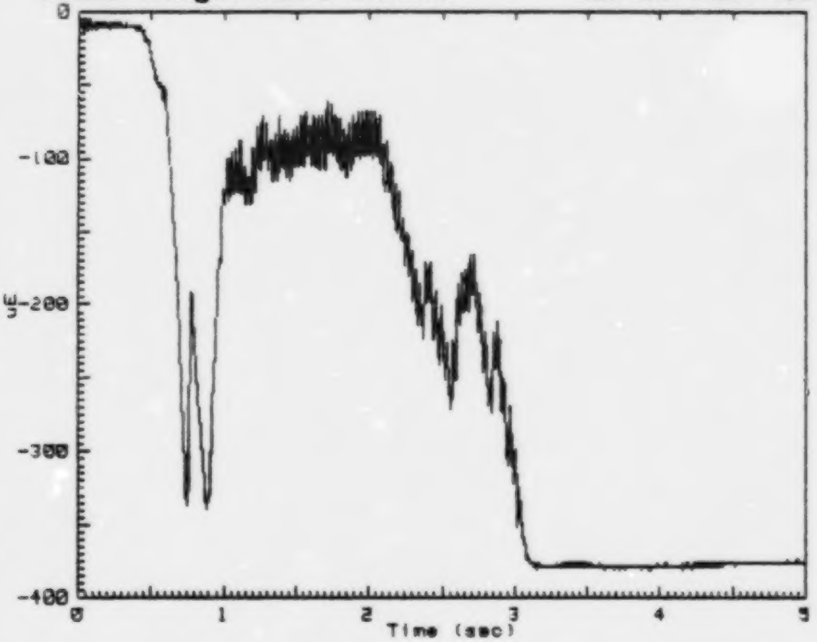
Blade Single-Axis Strain Series PBT Test 1



1857

GEOTECHnical Resources Ltd. ANALYSIS DATE: 6 May 1988

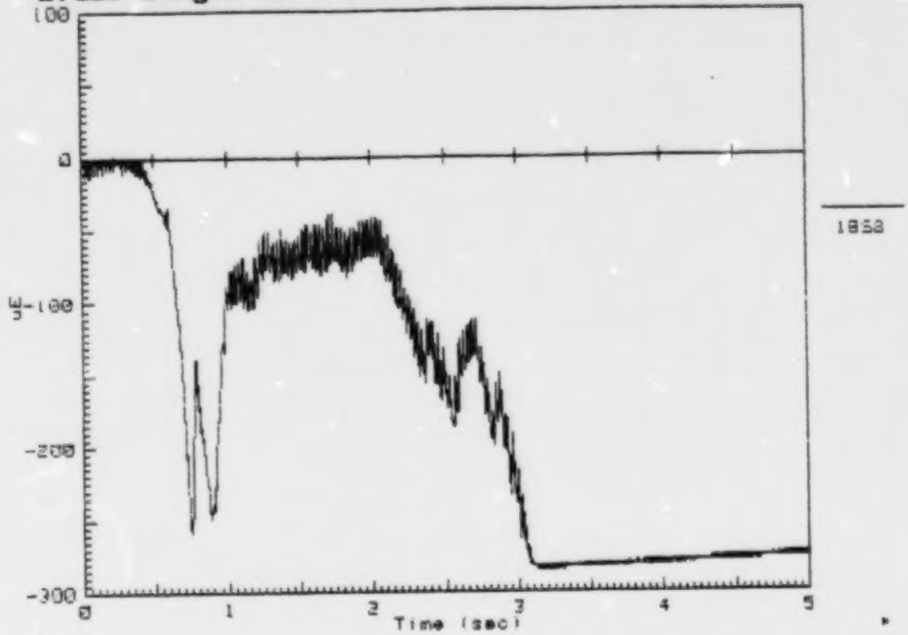
Blade Single-Axis Strain Series PBT Test 1



1856

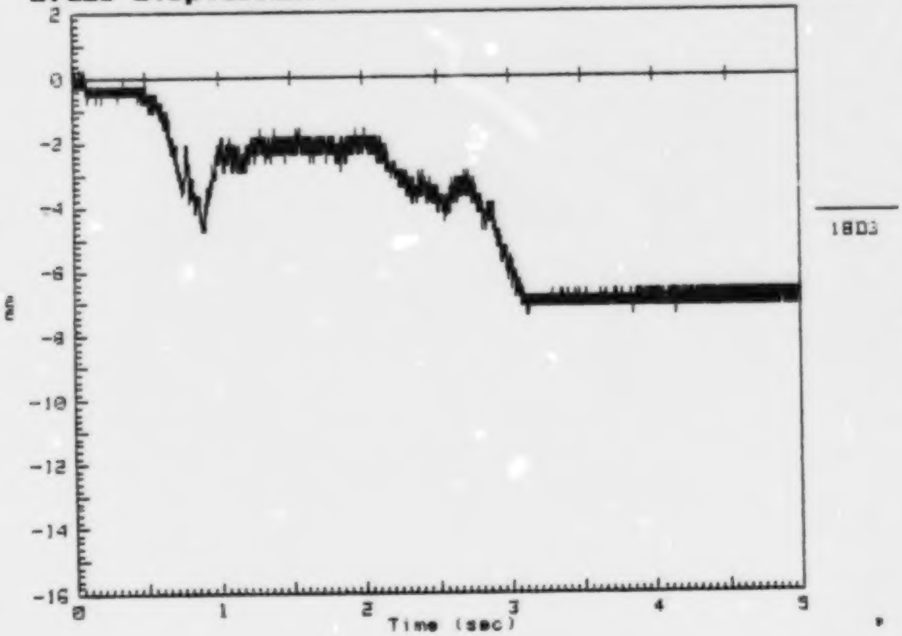
GEOTECHnical Resources Ltd. ANALYSIS DATE:30 May 1988

Blade Single-Axis Strain **Series PBT Test 1**



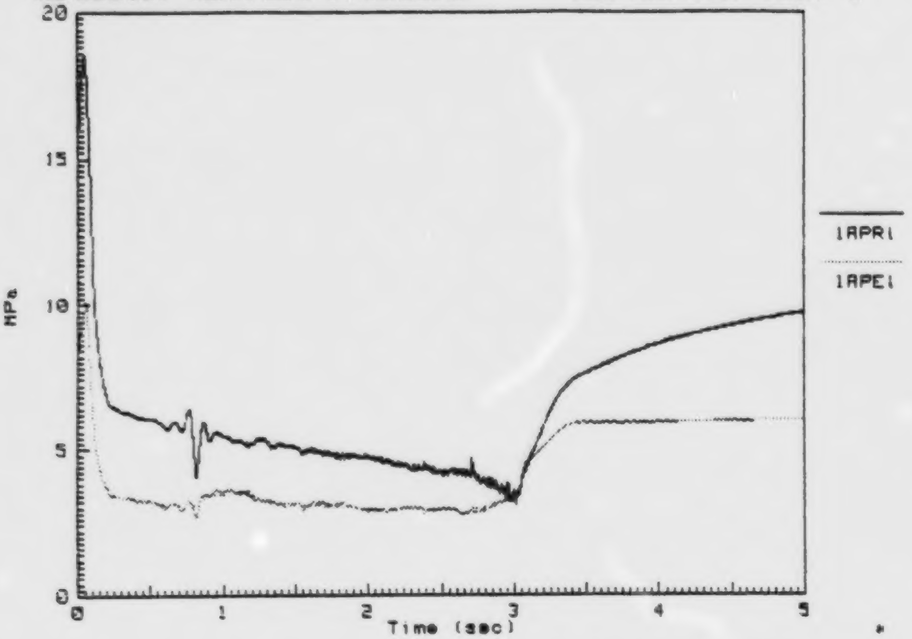
GEOTECHnical Resources Ltd. ANALYSIS DATE:30 May 1988

Blade Displacement **Series PBT Test 1**



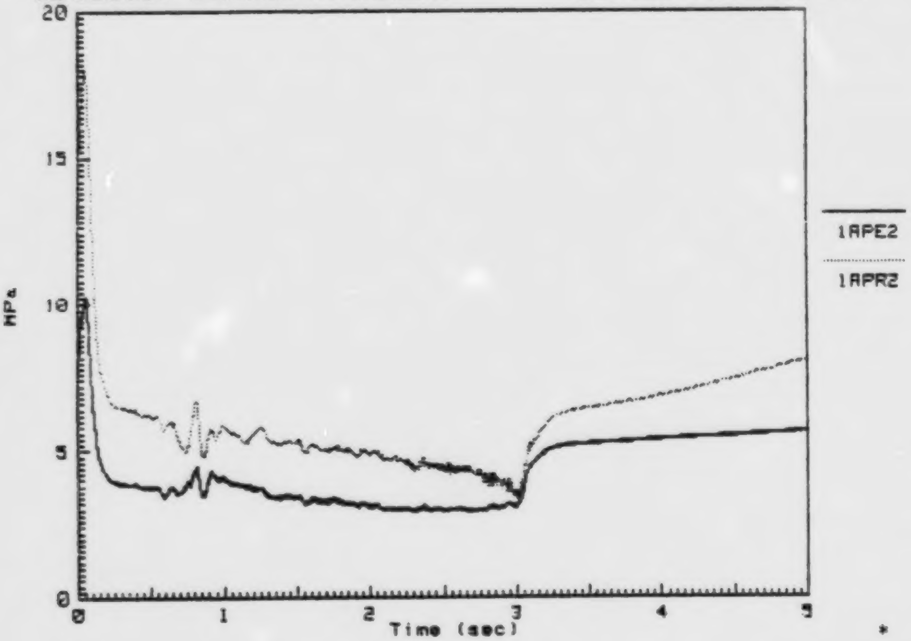
GEOTECHnical Resources Ltd. ANALYSIS DATE: 6 May 1988

Actuator Retract Pressure **Series PBT Test 1**



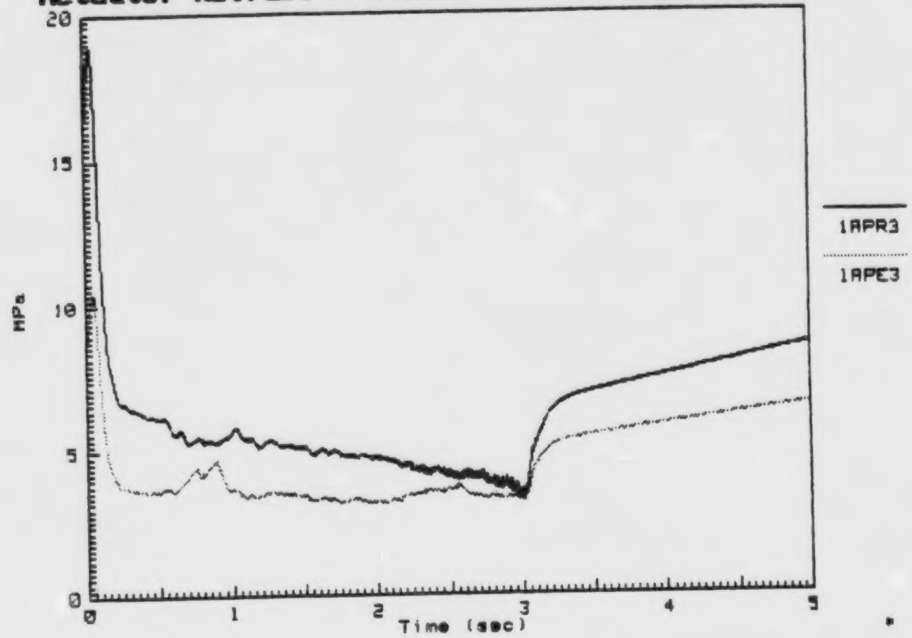
GEOTECHnical Resources Ltd. ANALYSIS DATE: 6 May 1988

Actuator Extend Pressure **Series PBT Test 1**



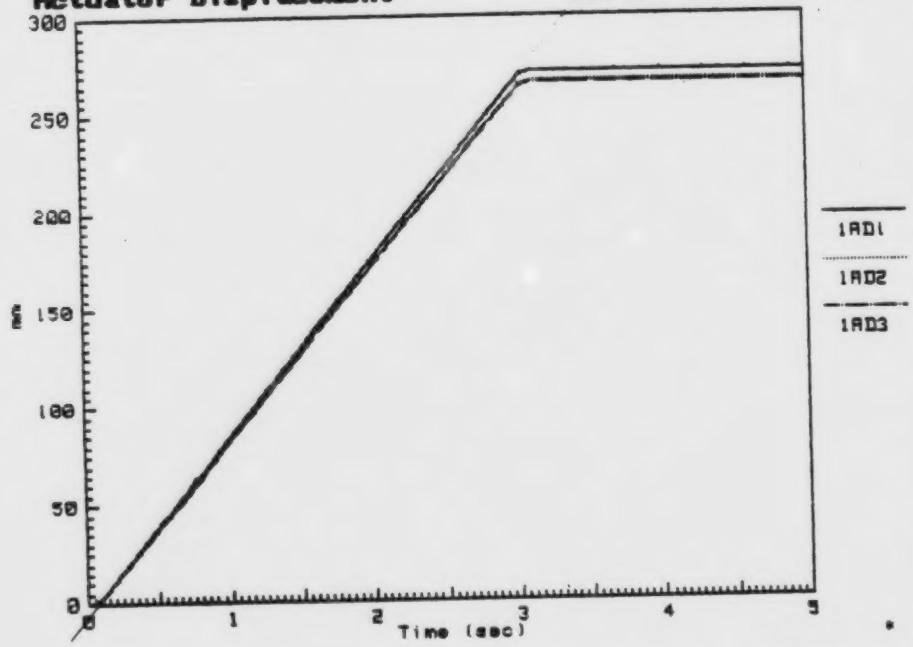
GEOTECHnical Resources Ltd. ANALYSIS DATE: 6 May 1988

Actuator Retract Pressure **Series PBT Test 1**



GEOTECHnical Resources Ltd. ANALYSIS DATE: 6 May 1988

Actuator Displacement **Series PBT Test 1**

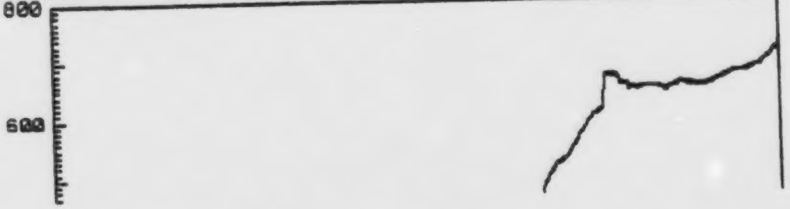


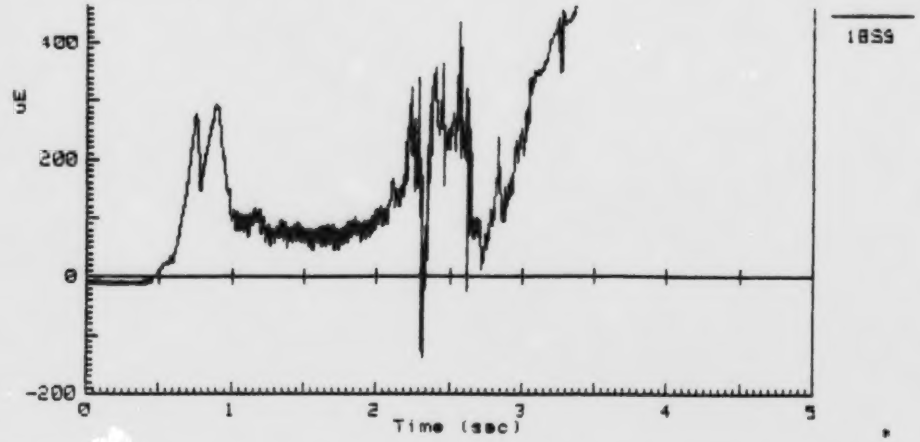
velocity = 300mm / 3.35 – .07

91.5mm/s

GEOTECHnical Resources Ltd. ANALYSIS DATE: 6 May 1988

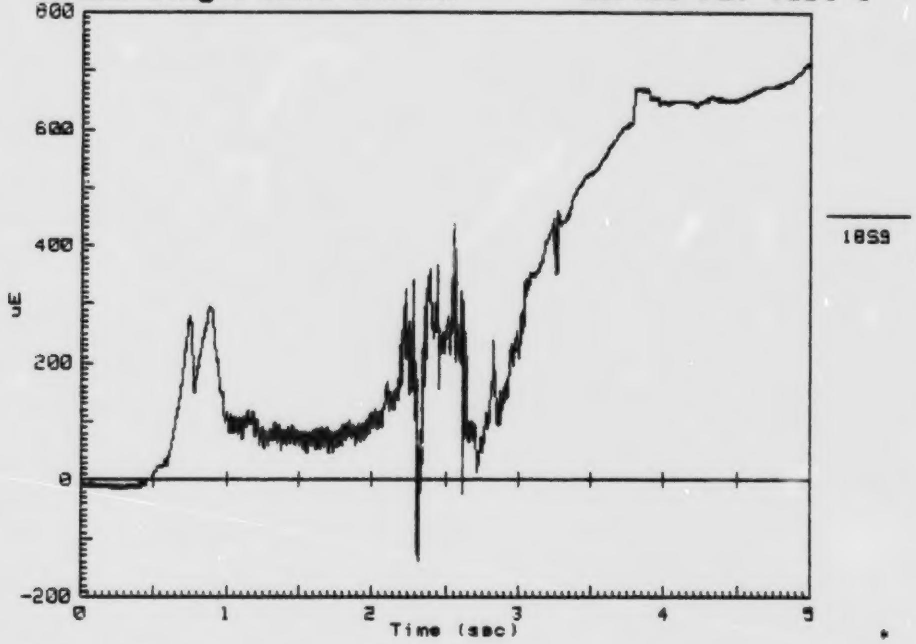
Blade Single-Axis Strain **Series PBT Test 1**





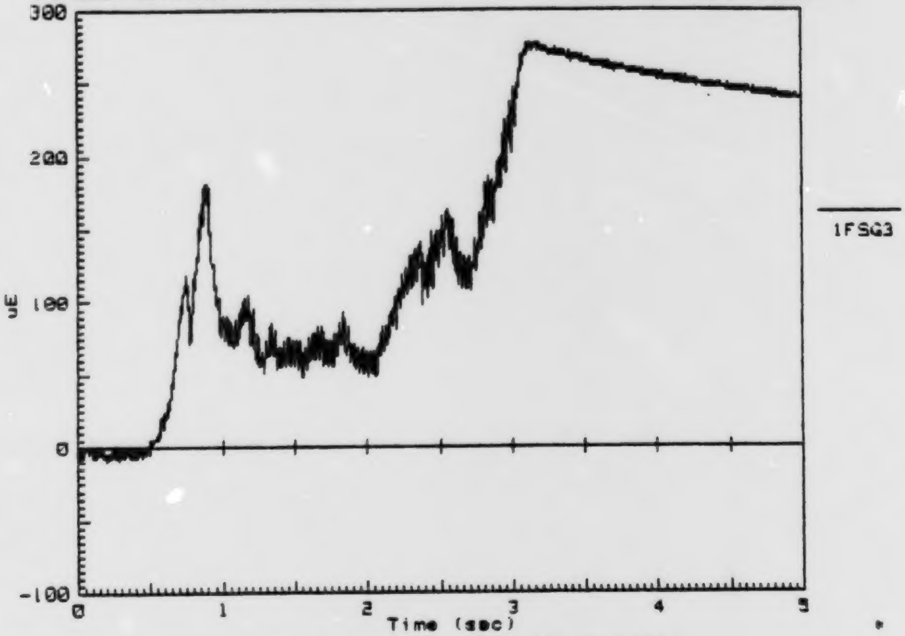
GEOTECHnical Resources Ltd.   ANALYSIS DATE: 6 May 1988

Blade Single-Axis Strain   Series PBT Test 1



GEOTECHnical Resources Ltd. ANALYSIS DATE: 6 May 1988

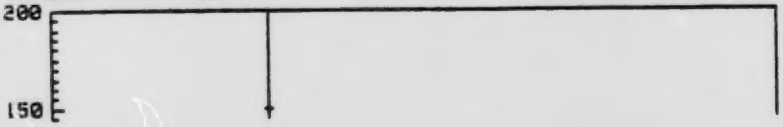
Frame Girder Strain **Series PBT Test 1**

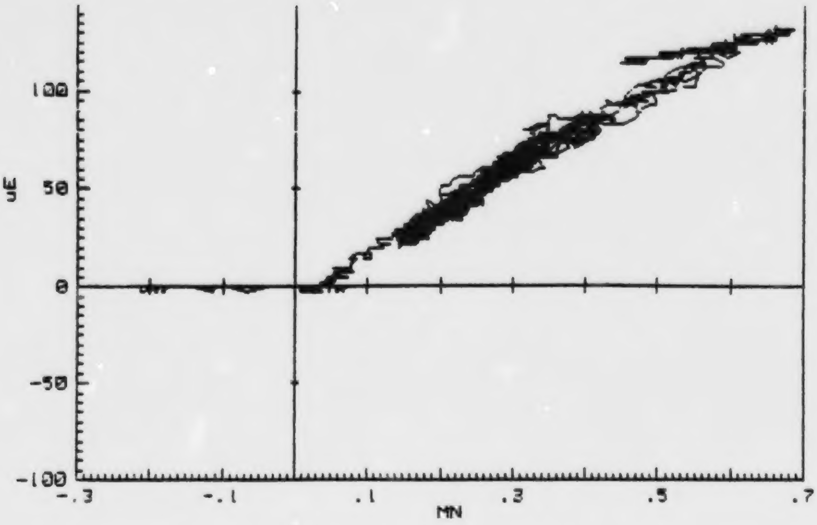


```
in buff_to_temp, buff_gain(*) =  .00208619439994
in buff_to_temp, buff_gain(*) =  1.37052891391E-5
```

GEOTECHnical Resources Ltd. ANALYSIS DATE: 6 May 1988

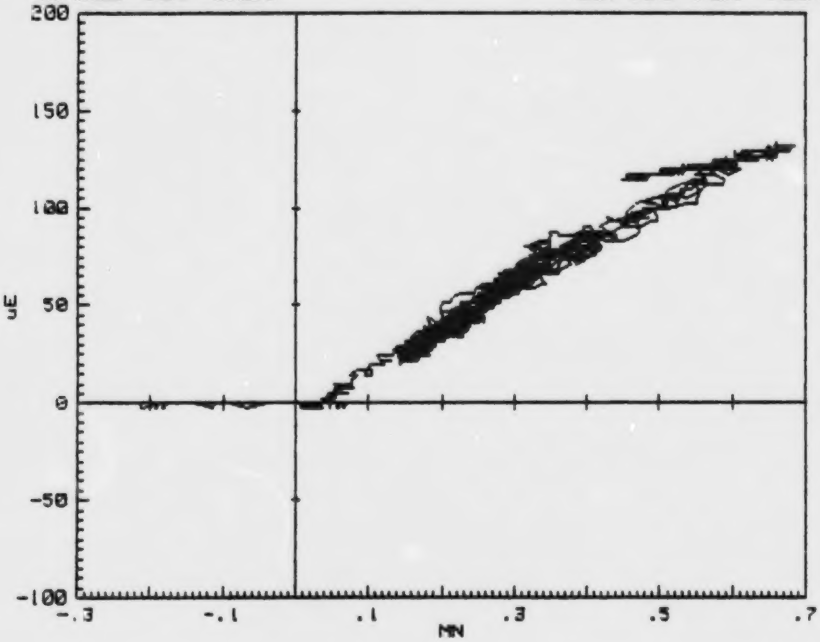
1FSG2 vs. 1ALT **Series PBT Test 1**





GEOTECHnical Resources Ltd. ANALYSIS DATE: 6 May 1988

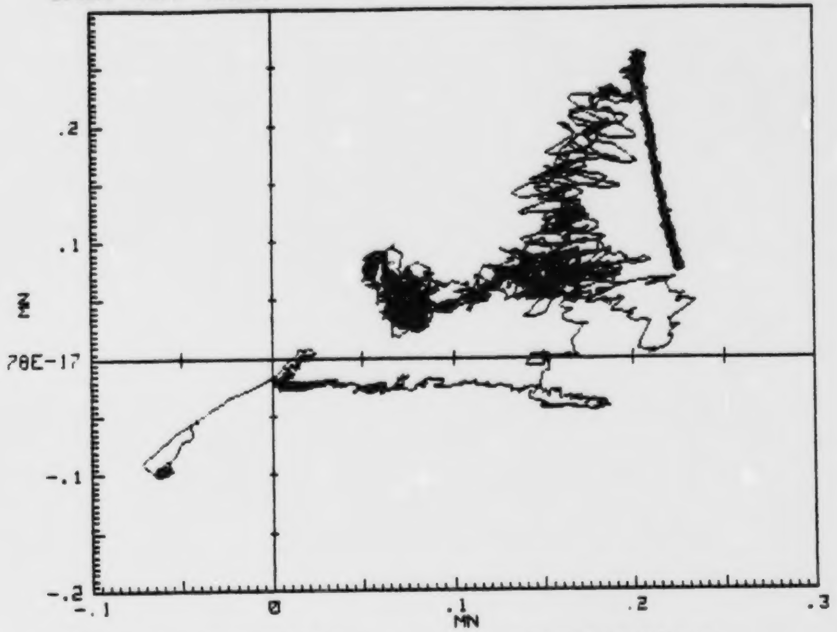
1FSG2 vs. 1ALT **Series PBT Test 1**



```
in buff_to_temp, buff_gain(*) =  5.54575346189E-6
in buff_to_temp, buff_gain(*) =  4.68159525251E-6
```

GEOTECHnical Resources Ltd.   ANALYSIS DATE: 6 May 1988

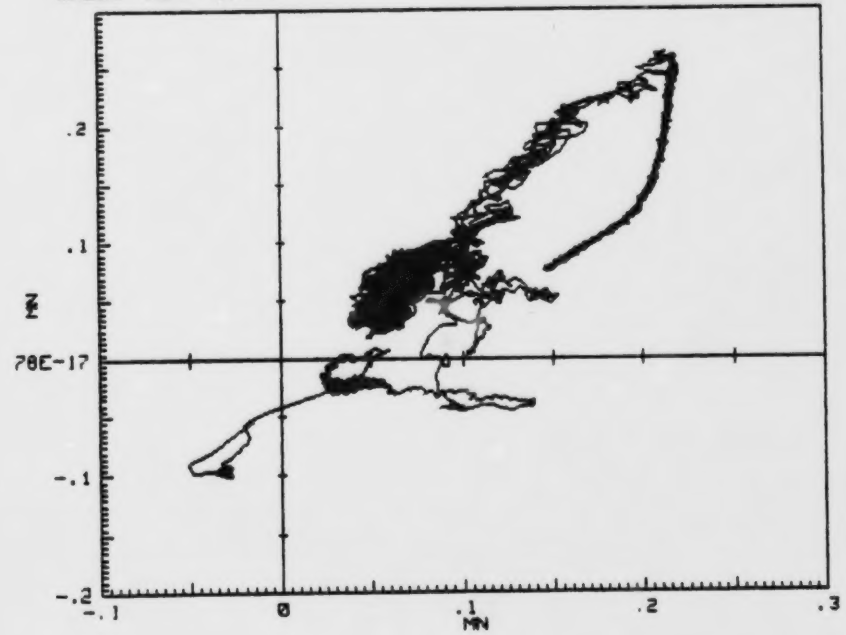
1AL1 vs. 1AL3   **Series PBT Test 1**



```
in buff_to_temp, buff_gain(*) =  5.54575346189E-6
in buff_to_temp, buff_gain(*) =  4.14453365806E-6
```

GEOTECHnical Resources Ltd.   ANALYSIS DATE: 6 May 1988

1AL1 vs. 1AL2   **Series PBT Test 1**



```
                    GEOTECHnical resources ltd
                           PROP BUSTERS
                      PROJECT NUMBER: 9448


Date: 10 May 1988
Time: 09:30:35

Test series...... PBT
Test number...... 2

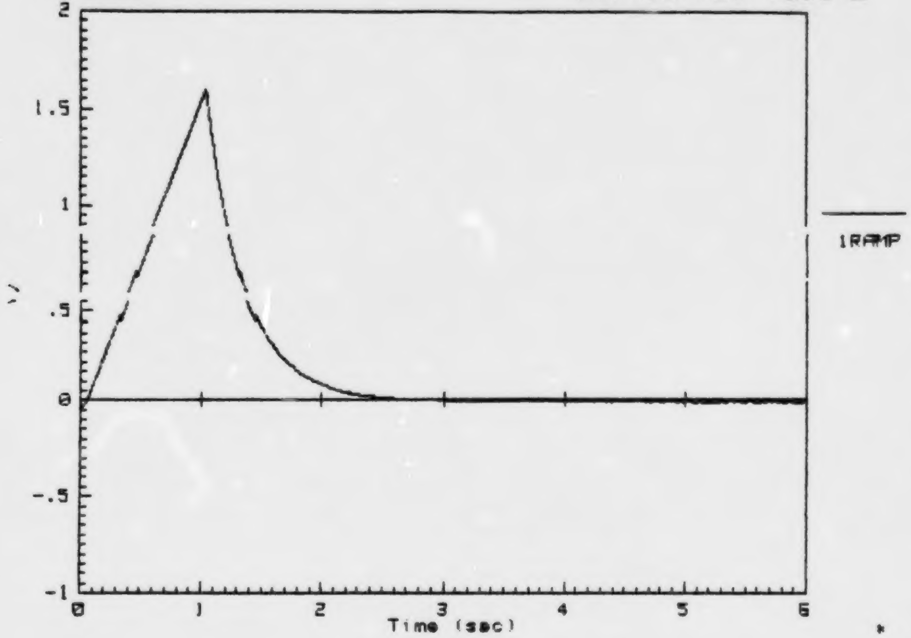
*** Window 1 ***
Test duration .................. 6 Second(s)
AD-200 sample period............ 16.1 Micro-second(s)
Sample rate, aggregate ......... 62111 Hz.
Sample rate per channel ........ 3881 Hz.
Number of samples per channel .. 23292 words.
Total number of samples ........ 745344 words.
Trigger source ................. INTERNAL
Number of cards ................ 2
Number of channels per card .... 16
Total number of channels ....... 32
```

Transducer table for test #PRT02_HDR

```
14690 Card1:!
14700    |-----|--|--|--|--|----|--------|--------|-------|------|---------|
14710    |Card |Ch|SW|HW|Fx|Mode| Gain   | Offset | Units |  Ch  | Serial  |
14720    | no. |no|gn|gn|gn|    | (eng/V)|  (V)   | (/V)  |  Id  | Number  |
14730    |-----|--|--|--|--|----|--------|--------|-------|------|---------|
14740    DATA 1, 1, 1, 1, 1, "S",  53.643,  2.8613,   "mm", "BD1",  "A33380"
14750    DATA 1, 2, 1, 1, 1, "S",  53.711,  2.8955,   "mm", "BD2",  "A22090"
14760    DATA 1, 3, 1, 1, 1, "S",  53.711,  2.4292,   "mm", "BD3",  "A22091"
14770    DATA 1, 4, 1, 1, 1, "S",  6.8529,  0.0879,  "MPa","APR1",    "5817"
14780    DATA 1, 5, 1, 1, 1, "S",  6.8586,  0.0049,  "MPa","APF1",    "4986"
14790    DATA 1, 6, 1, 1, 1, "S",  6.8792,  0.0562,  "MPa","APR2",    "5723"
14800    DATA 1, 7, 1, 1, 1, "S",  6.8636,  0.0708,  "MPa","APF2",    "5815"
14810    DATA 1, 8, 1, 1, 1, "S",  6.8643,  0.0806,  "MPa","APR3",    "5883"
14820    DATA 1, 9, 1, 1, 1, "S",  6.8531,  0.0562,  "MPa","APF3",    "5885"
14830    DATA 1,10, 1, 1, 1, "S",  13.709,  0.0830,  "MPa", "BP1",    "5887"
14840    DATA 1,11, 1, 1, 1, "S",  13.712,  0.0757,  "MPa", "BP2",    "5773"
14850    DATA 1,12, 1, 1, 1, "S",  13.734,  0.0903,  "MPa", "BP3",    "5892"
14860    DATA 1,13, 1, 1, 1, "S",  13.731,  0.0098,  "MPa", "BP4",    "5889"
14870    DATA 1,14, 1, 1, 1, "S",  13.717,  0.0000,  "MPa", "BP5",    "5891"
14880    DATA 1,15, 1, 1, 2, "S",     1.0,       0,  "  V","RAMP",  "       "
14890    DATA 1,16, 1, 1, 1, "S",  1000.0,       0,   "uF","BR1B",  "       "
14900 Card2:!
14910    DATA 2, 1 ,1, 1, 2, "S",  53.906,  1.3965,   "mm", "AD1",  "A22091"
14920    DATA 2, 2, 1, 1, 2, "S",  53.634,  1.3623,   "mm", "AD2",  "A33381"
14930    DATA 2, 3, 1, 1, 2, "S",  53.608,  1.5918,   "mm", "AD3",  "A33382"
14940    DATA 2, 4, 1, 1, 1, "S",  1000.0,       0,   "uF","BR1A",  "       "
14950    DATA 2, 5, 1, 1, 1, "S",  1000.0,       0,   "uF","ES62",  "       "
14960    DATA 2, 6, 1, 1, 1, "S",  1000.0,       0,   "uF","ES63",  "       "
14970    DATA 2, 7, 1, 1, 1, "S",  1000.0,       0,   "uF", "BS7",  "       "
14980    DATA 2, 8, 1, 1, 1, "S",  1000.0,       0,   "uF", "BS8",  "       "
14990    DATA 2, 9, 1, 1, 1, "S",  1000.0,       0,   "uF", "BS9",  "       "
15000    DATA 2,10, 1, 1, 1, "S",  1000.0,       0,   "uF", "BS1",  "       "
15010    DATA 2,11, 1, 1, 1, "S",  1000.0,       0,   "uF","BR2B",  "       "
15020    DATA 2,12, 1, 1, 1, "S",  1000.0,       0,   "uF", "BS3",  "       "
15030    DATA 2,13, 1, 1, 1, "S",  1000.0,       0,   "uF", "BS4",  "       "
15040    DATA 2,14, 1, 1, 1, "S",  1000.0,       0,   "uF", "BS5",  "       "
15050    DATA 2,15, 1, 1, 1, "S",  1000.0,       0,   "uF", "BS6",  "       "
15060    DATA 2,16, 1, 1, 1, "S",  1000.0,       0,   "uF","BR1C",  "       "
15070    |-----|--|--|--|--|----|--------|--------|-------|------|---------|
15080    |Card |Ch|SW|HW|Fx|Mode| Gain   | Offset | Units |  Ch  | Serial  |
15090    | no. |no|gn|gn|gn|    | (Eng/V)|  (V)   | (/V)  |  Id  | Number  |
15100    |-----|--|--|--|--|----|--------|--------|-------|------|---------|
15110 End_transducers:!
```

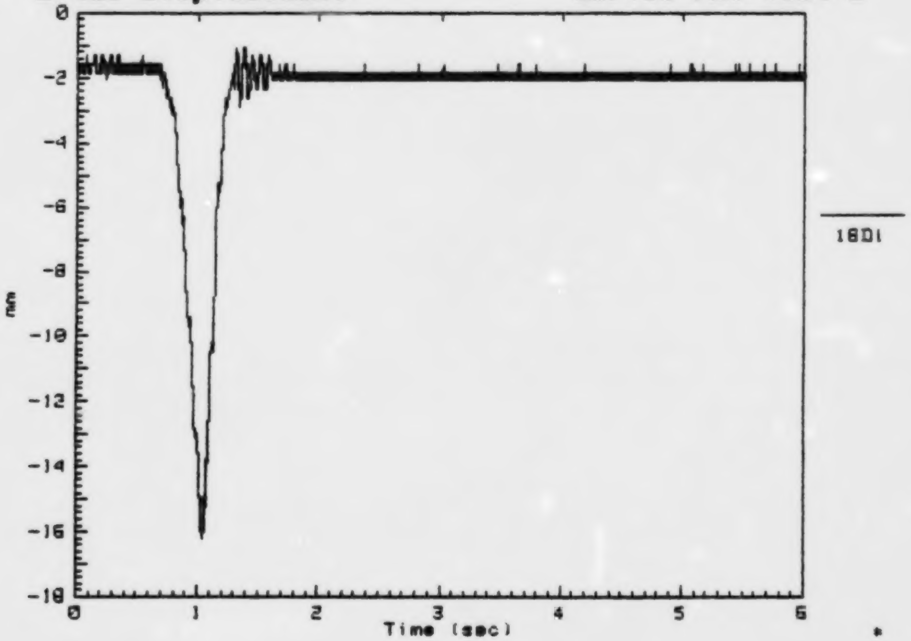
GEOTECHnical Resources Ltd. ANALYSIS DATE:30 May 1988

Command **Series PBT Test 2**



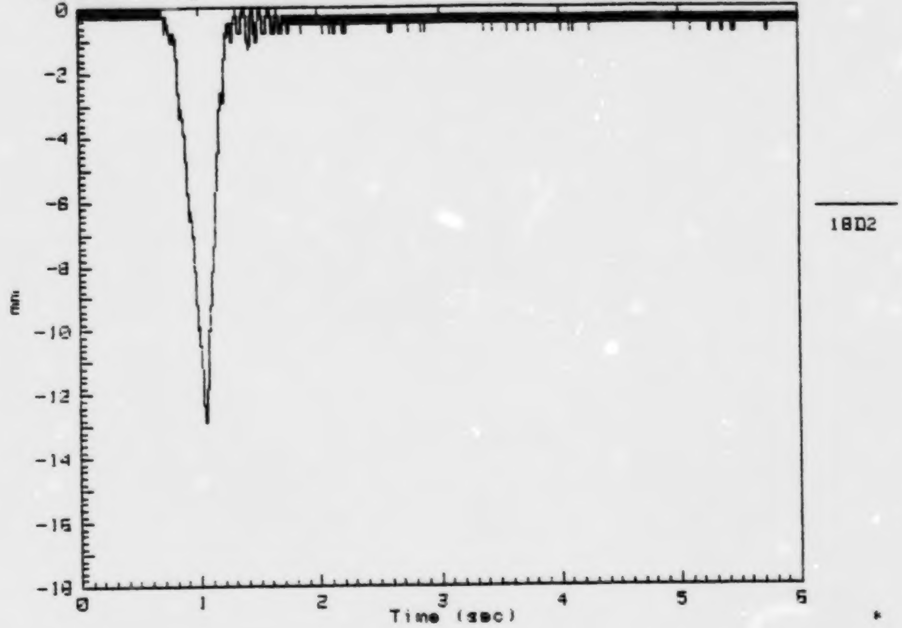
GEOTECHnical Resources Ltd. ANALYSIS DATE:30 May 1988

Blade Displacement **Series PBT Test 2**



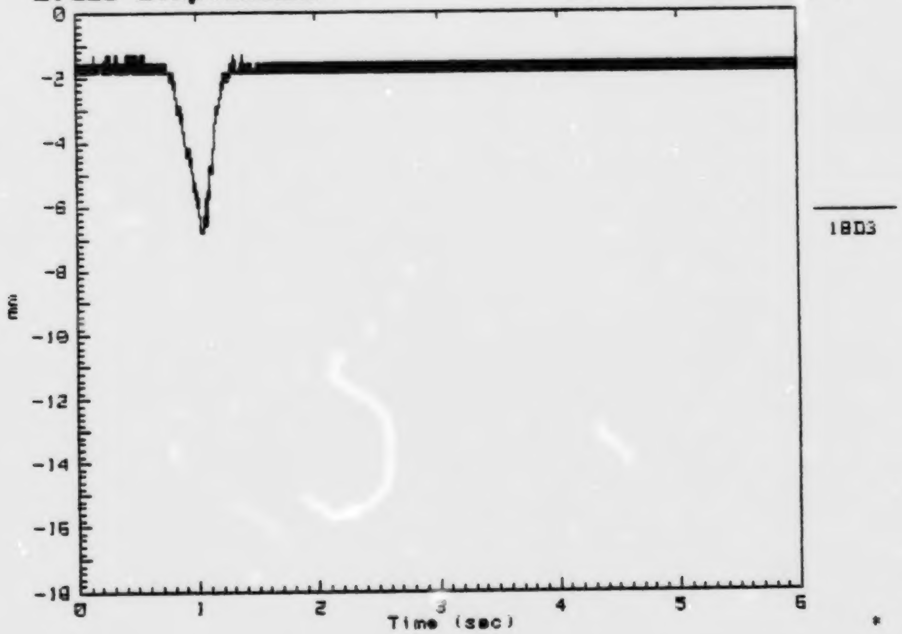
GEOTECHnical Resources Ltd. ANALYSIS DATE:30 May 1988

Blade Displacement **Series PBT Test 2**



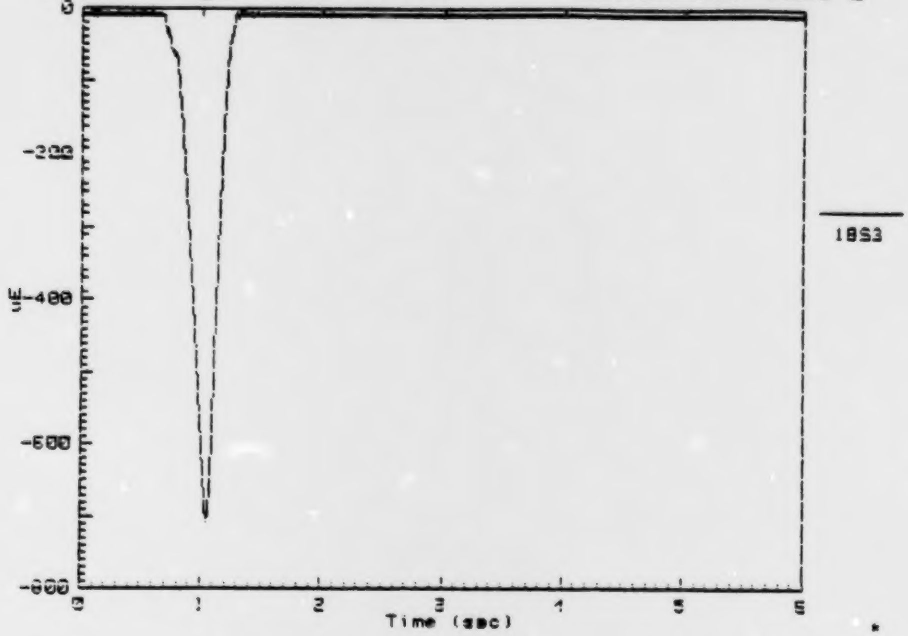
GEOTECHnical Resources Ltd. ANALYSIS DATE:30 May 1988

Blade Displacement **Series PBT Test 2**



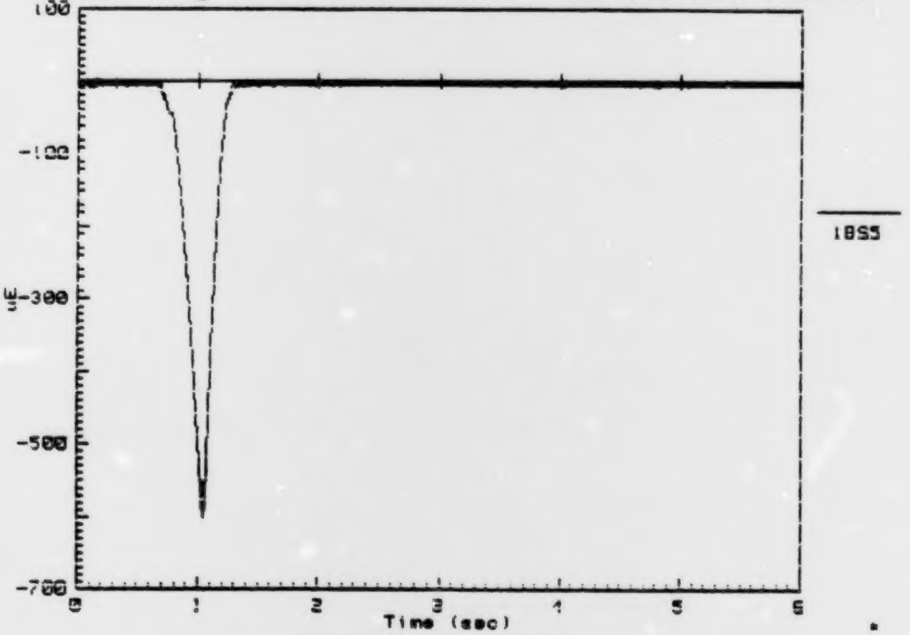
GEOTECHnical Resources Ltd.   ANALYSIS DATE:10 May 1988

Blade Single-Axis Strain   Series PBT Test 2



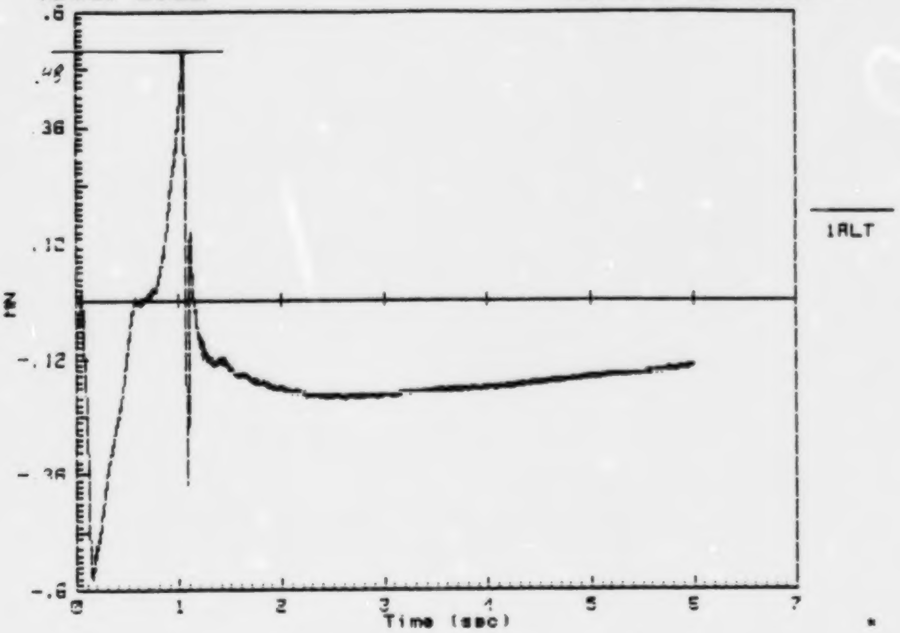
GEOTECHnical Resources Ltd.   ANALYSIS DATE:10 May 1988

Blade Single-Axis Strain   Series PBT Test 2



GEOTECHnical Resources Ltd. ANALYSIS DATE: 10 May 1988

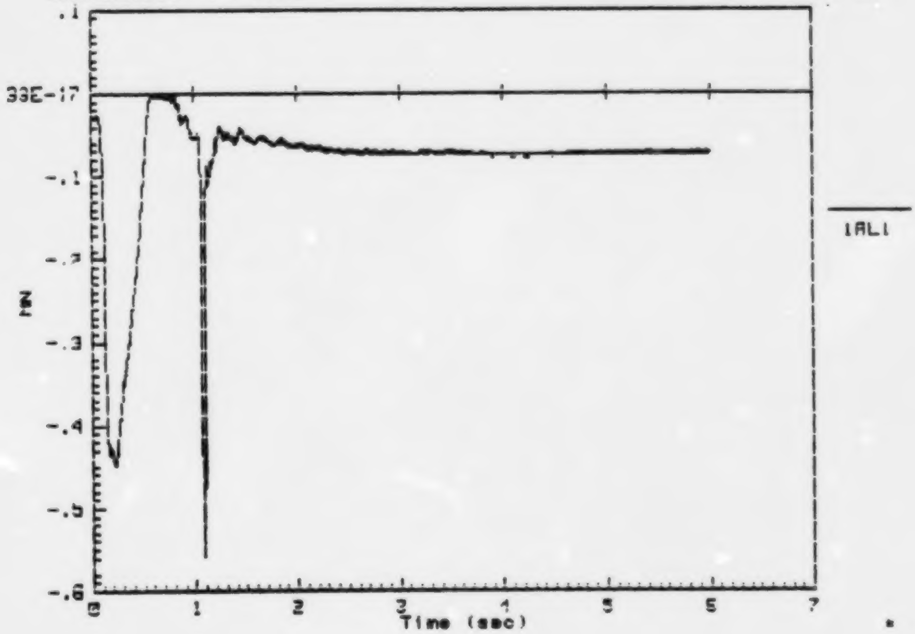
Total Load **Series PBT Test 2**



Peak [illegible]
≐ .52 MN

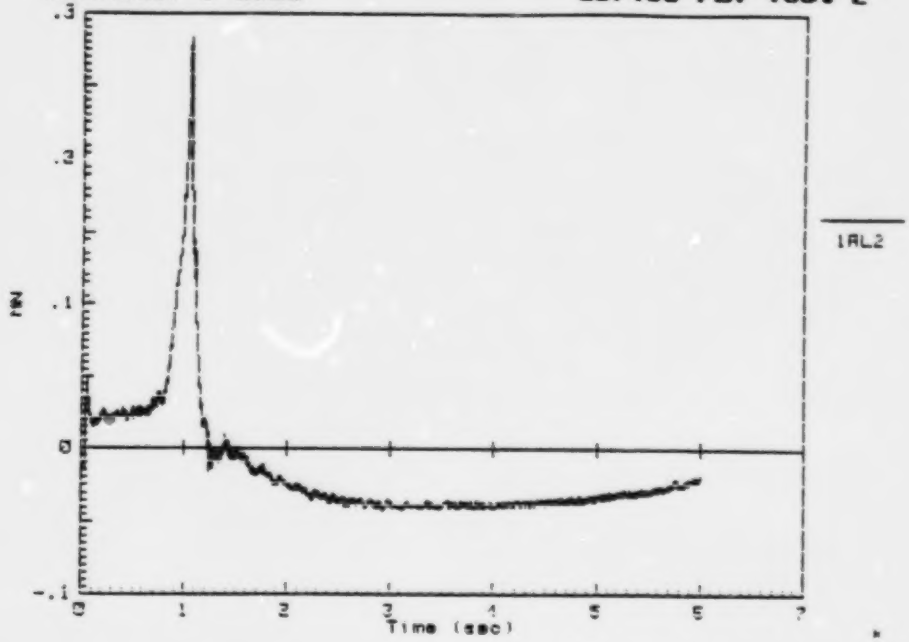
GEOTECHnical Resources Ltd. ANALYSIS DATE: 10 May 1988

Actuator 1 Load **Series PBT Test 2**



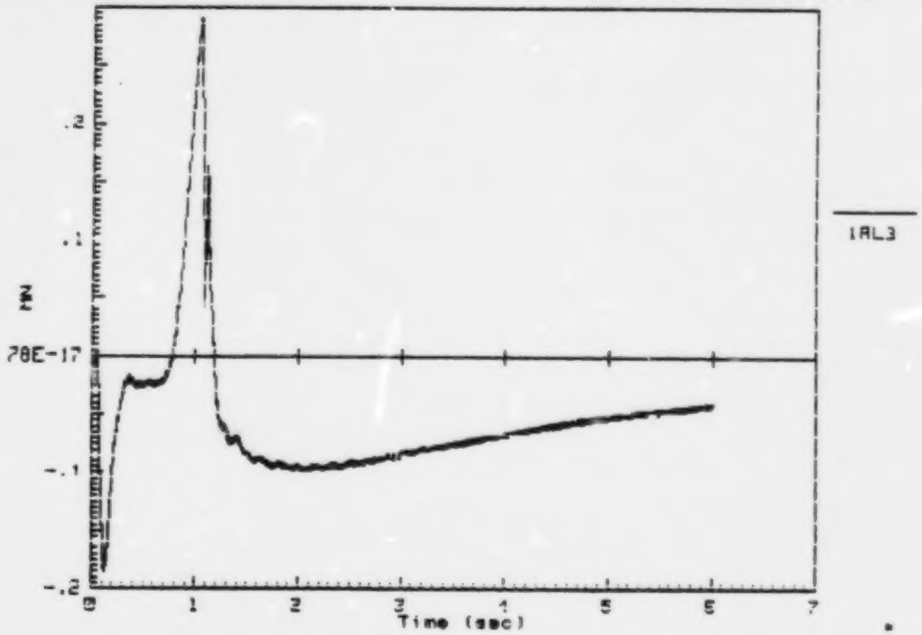
GEOTECHnical Resources Ltd. ANALYSIS DATE:10 May 1988

Actuator 2 Load **Series PBT Test 2**



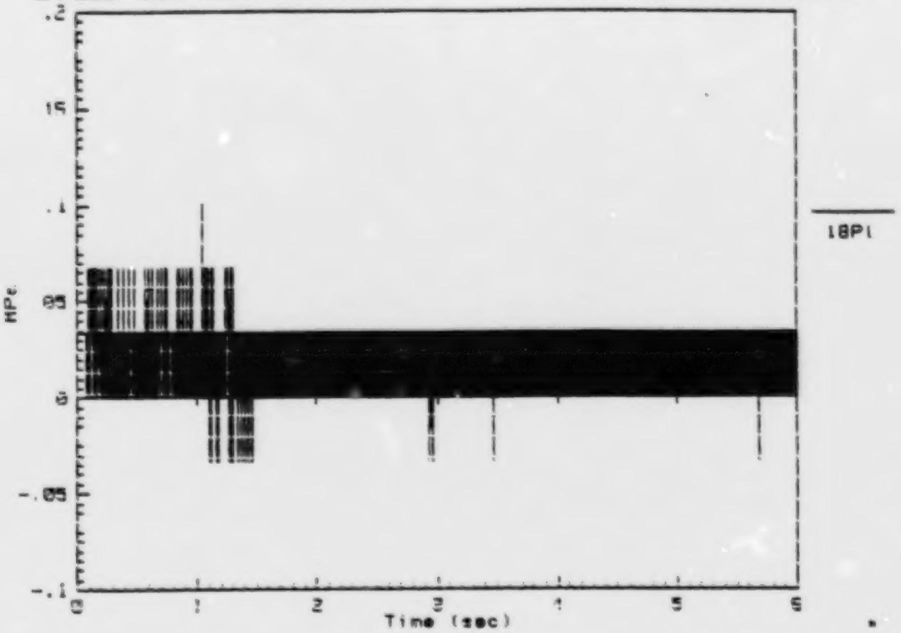
GEOTECHnical Resources Ltd. ANALYSIS DATE:10 May 1988

Actuator 3 Load **Series PBT Test 2**



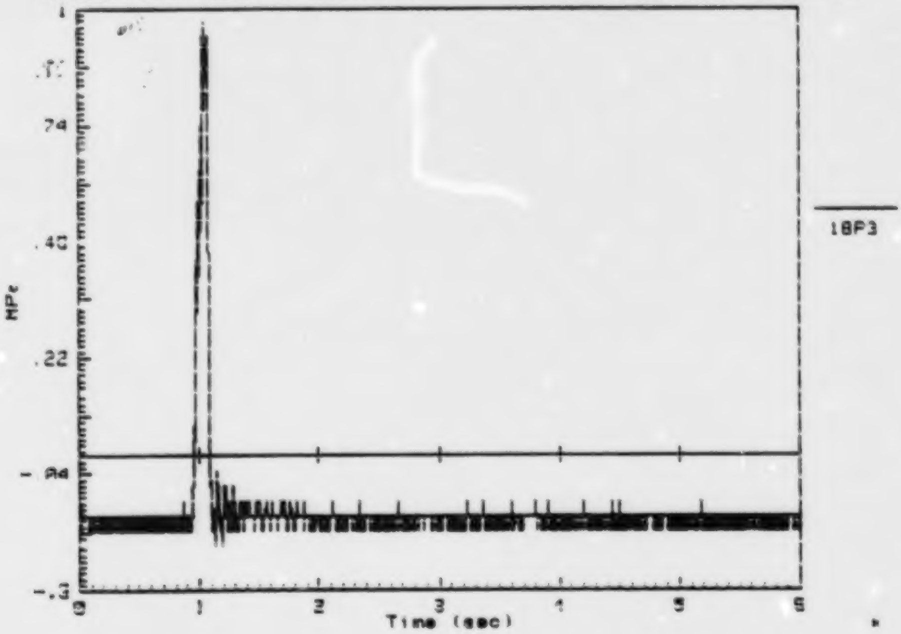
GEOTECHnical Resources Ltd. ANALYSIS DATE: 18 May 1988

Blade Surface Pressure **Series PBT Test 2**



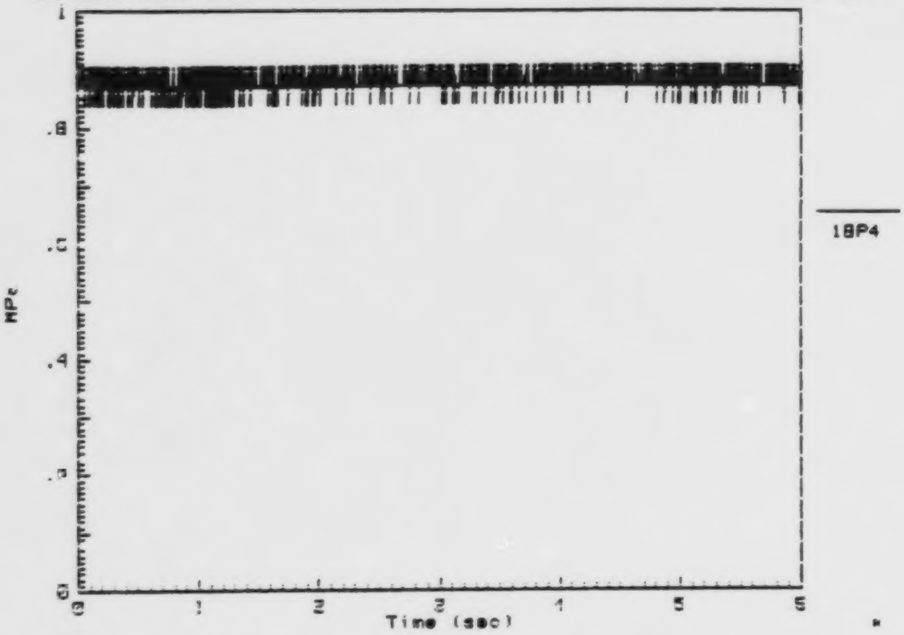
GEOTECHnical Resources Ltd. ANALYSIS DATE: 18 May 1988

Blade Surface Pressure **Series PBT Test 2**



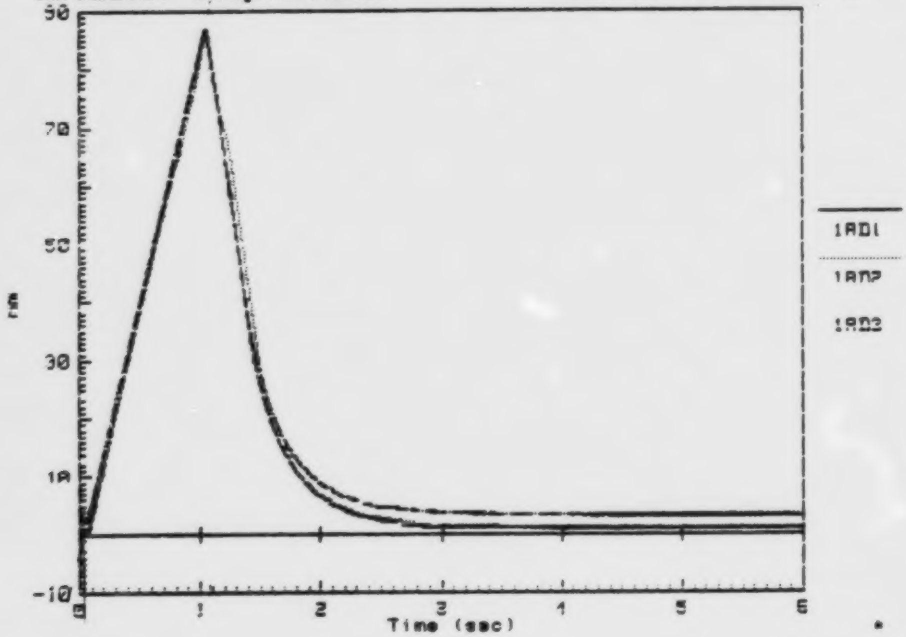
GEOTECHnical Resources Ltd. ANALYSIS DATE:10 May 1988

Blade Surface Pressure **Series PBT Test 2**



GEOTECHnical Resources Ltd. ANALYSIS DATE:10 May 1988

Actuator Displacement **Series PBT Test 2**



```
                    GEOTECHnical resources ltd
                           PROP BUSTERS
                       PROJECT NUMBER: 9448


Date: 10 May 1988
Time: 13:54:13

Test series...... PBT
Test number...... 3

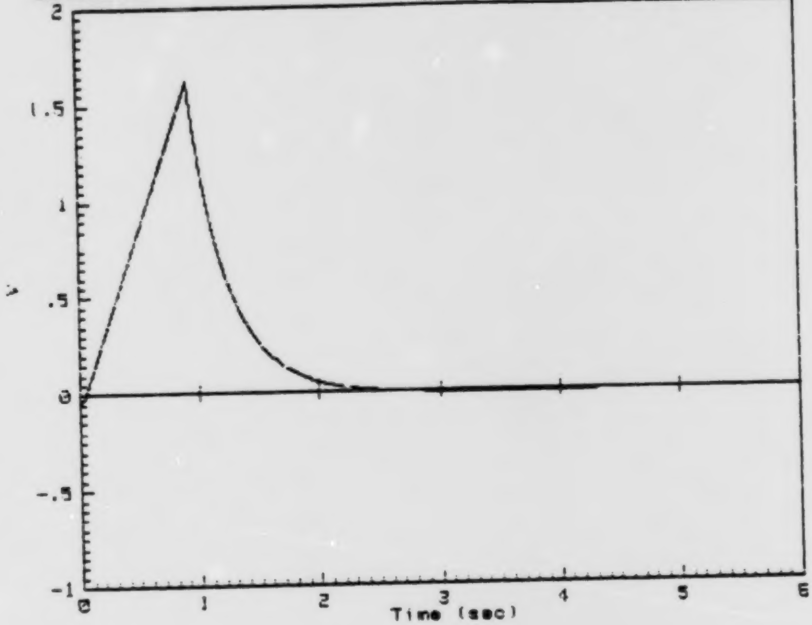
*** Window 1 ***
Test duration .................. 6 Second(s)
AD-200 sample period............ 16.1 Micro-second(s)
Sample rate, aggregate ......... 62111 Hz.
Sample rate per channel ........ 3881 Hz.
Number of samples per channel .. 23292 words.
Total number of samples ........ 745344 words.
Trigger source ................. INTERNAL
Number of cards ................ 2
Number of channels per card .... 16
Total number of channels ....... 32
```

Transducer table for test #PBT03_HDR

```
14690 Card1:!
14700    !-----!--!--!--!--!----!--------!--------!-------!------!---------!
14710    !Card !Ch!SW!HW!Ex!Mode!  Gain   ! Offset ! Units !  Ch  !  Serial !
14720    ! no. !no!gn!gn!gn!    ! (eng/V)!  (V)   ! (/V)  !  Id  !  Number !
14730    !-----!--!--!--!--!----!--------!--------!-------!------!---------!
14740    DATA 1, 1, 1, 1, 1, "S",  107.29,  2.9028,   "mm", "BD1",  "A33380"
14750    DATA 1, 2, 1, 1, 1, "S",  107.42,  2.9517,   "mm", "BD2",  "A22090"
14760    DATA 1, 3, 1, 1, 1, "S",  107.42,  2.4609,   "mm", "BD3",  "A22091"
14770    DATA 1, 4, 1, 1, 1, "S",  6.8529,  0.0879,  "MPa","APR1",    "5817"
14780    DATA 1, 5, 1, 1, 1, "S",  6.8586,  0.0049,  "MPa","APE1",    "4986"
14790    DATA 1, 6, 1, 1, 1, "S",  6.8792,  0.0562,  "MPa","APR2",    "5723"
14800    DATA 1, 7, 1, 1, 1, "S",  6.8636,  0.0708,  "MPa","APE2",    "5815"
14810    DATA 1, 8, 1, 1, 1, "S",  6.8643,  0.0806,  "MPa","APR3",    "5883"
14820    DATA 1, 9, 1, 1, 1, "S",  6.8531,  0.0562,  "MPa","APE3",    "5885"
14830    DATA 1,10, 1, 1, 1, "S",  13.709,  0.0830,  "MPa", "BP1",    "5887"
14840    DATA 1,11, 1, 1, 1, "S",  13.712,  0.0757,  "MPa", "BP2",    "5773"
14850    DATA 1,12, 1, 1, 1, "S",  13.734,  0.0903,  "MPa", "BP3",    "5892"
14860    DATA 1,13, 1, 1, 1, "S",  13.731,  0.0098,  "MPa", "BP4",    "5889"
14870    DATA 1,14, 1, 1, 1, "S",  13.717,  0.0000,  "MPa", "BP5",    "5891"
14880    DATA 1,15, 1, 1, 2, "S",     1.0,       0,  "  V","RAMP",  "       "
14890    DATA 1,16, 1, 1, 1, "S",  1000.0,       0,   "uE","BR1B",  "       "
14900 Card2:!
14910    DATA 2, 1 ,1, 1, 2, "S",  53.906,  1.4160,   "mm", "AD1",  "A22091"
14920    DATA 2, 2, 1, 1, 2, "S",  53.634,  1.4014,   "mm", "AD2",  "A33381"
14930    DATA 2, 3, 1, 1, 2, "S",  53.608,  1.6895,   "mm", "AD3",  "A33382"
14940    DATA 2, 4, 1, 1, 1, "S",  1000.0,       0,   "uE","BR1A",  "       "
14950    DATA 2, 5, 1, 1, 1, "S",  1000.0,       0,   "uE","FSG2",  "       "
14960    DATA 2, 6, 1, 1, 1, "S",  1000.0,       0,   "uE","FSG3",  "       "
14970    DATA 2, 7, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS7",  "       "
14980    DATA 2, 8, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS8",  "       "
14990    DATA 2, 9, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS9",  "       "
15000    DATA 2,10, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS1",  "       "
15010    DATA 2,11, 1, 1, 1, "S",  1000.0,       0,   "uE","BR2B",  "       "
15020    DATA 2,12, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS3",  "       "
15030    DATA 2,13, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS4",  "       "
15040    DATA 2,14, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS5",  "       "
15050    DATA 2,15, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS6",  "       "
15060    DATA 2,16, 1, 1, 1, "S",  1000.0,       0,   "uE","BRIC",  "       "
15070    !-----!--!--!--!--!----!--------!--------!-------!------!---------!
15080    !Card !Ch!SW!HW!Ex!Mode!  Gain   ! Offset ! Units !  Ch  !  Serial !
15090    ! no. !no!gn!gn!gn!    ! (Eng/V)!  (V)   ! (/V)  !  Id  !  Number !
15100    !-----!--!--!--!--!----!--------!--------!-------!------!---------!
15110 End_transducers:!
```

GEOTECHnical Resources Ltd. ANALYSIS DATE:10 May 1988

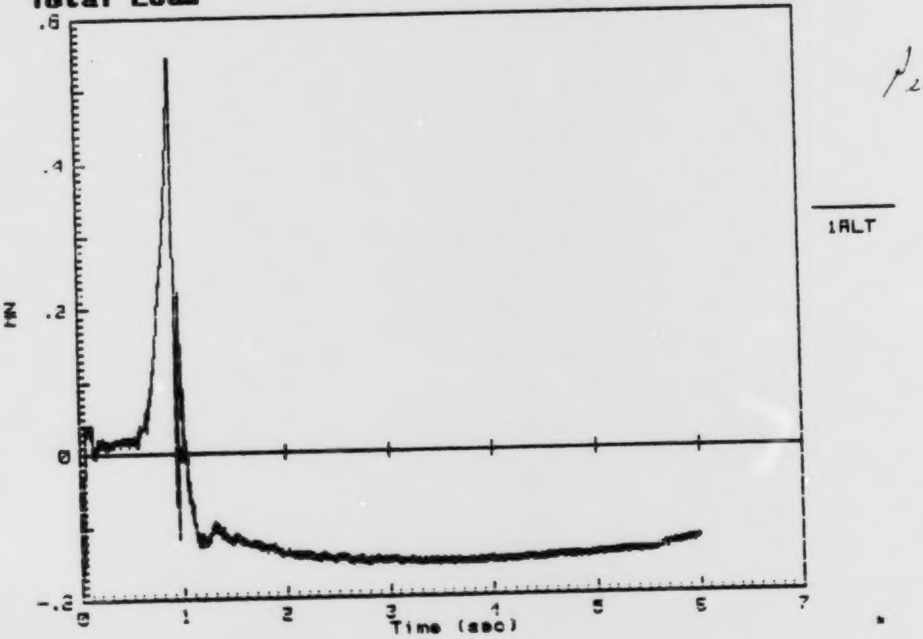
Command **Series PBT Test 3**



[illegible]

GEOTECHnical Resources Ltd. ANALYSIS DATE:10 May 1988

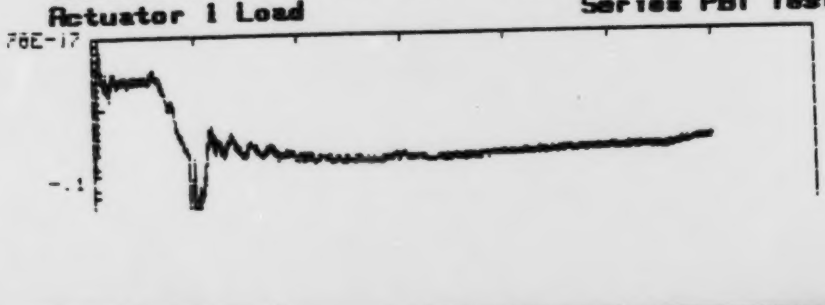
Total Load **Series PBT Test 3**

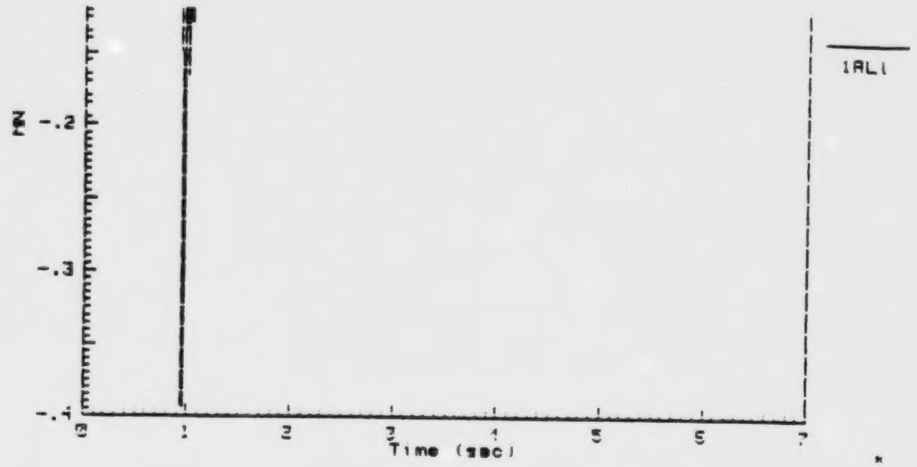


Peak load
≐ .58 kN

GEOTECHnical Resources Ltd. ANALYSIS DATE:10 May 1988

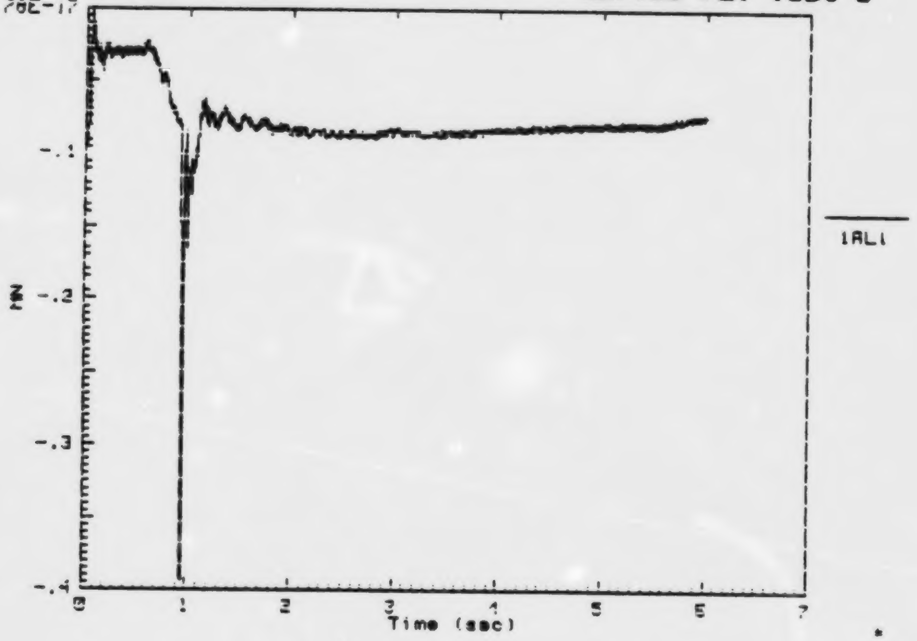
Actuator 1 Load **Series PBT Test 3**





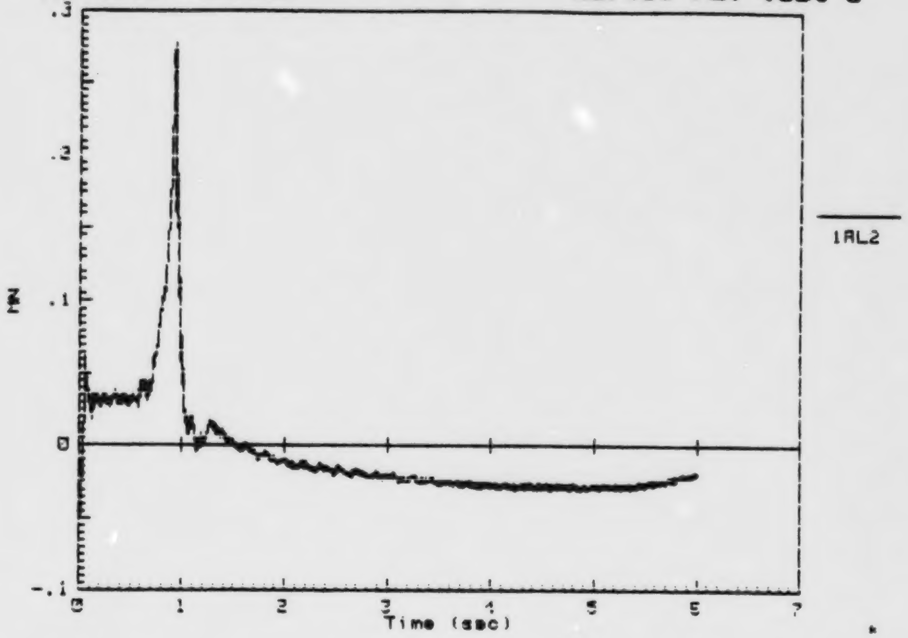
GEOTECHnical Resources Ltd.   ANALYSIS DATE:10 May 1988

Actuator 1 Load   **Series PBT Test 3**



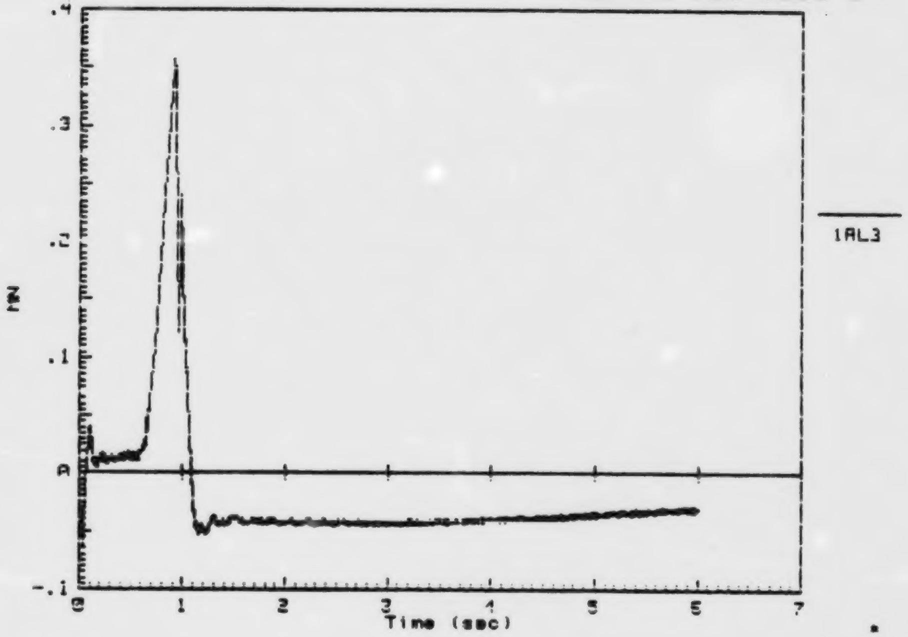
GEOTECHnical Resources Ltd.   ANALYSIS DATE:10 May 1988

Actuator 2 Load **Series PBT Test 3**



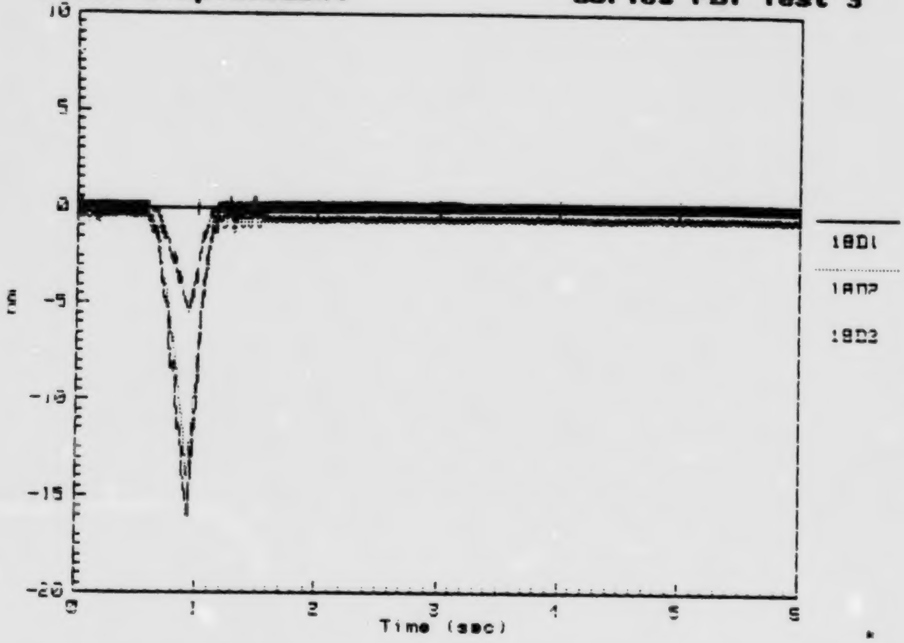
GEOTECHnical Resources Ltd.   ANALYSIS DATE:10 May 1988

Actuator 3 Load **Series PBT Test 3**



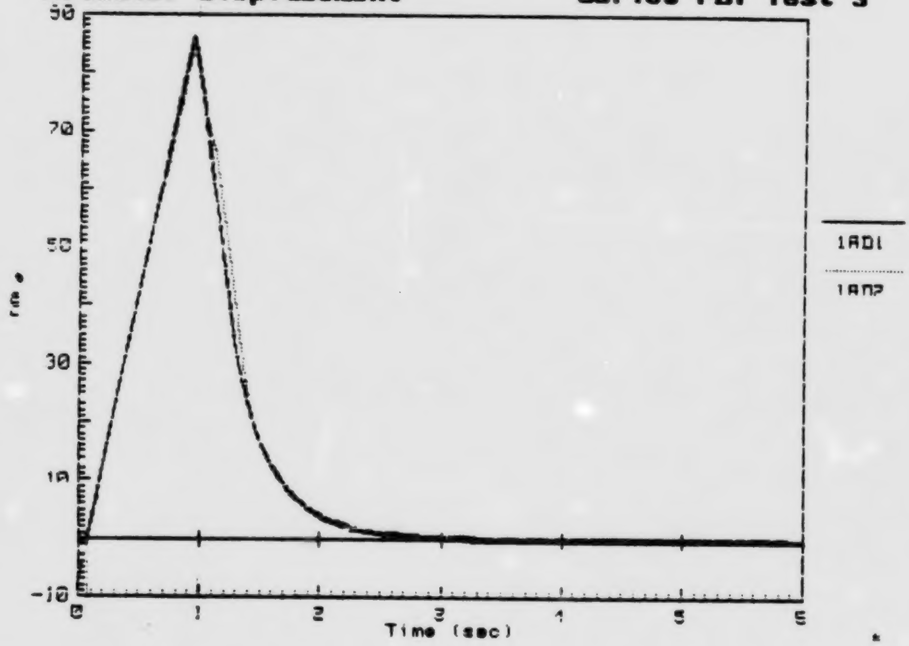
GEOTECHnical Resources Ltd. ANALYSIS DATE:10 May 1988

Blade Displacement **Series PBT Test 3**



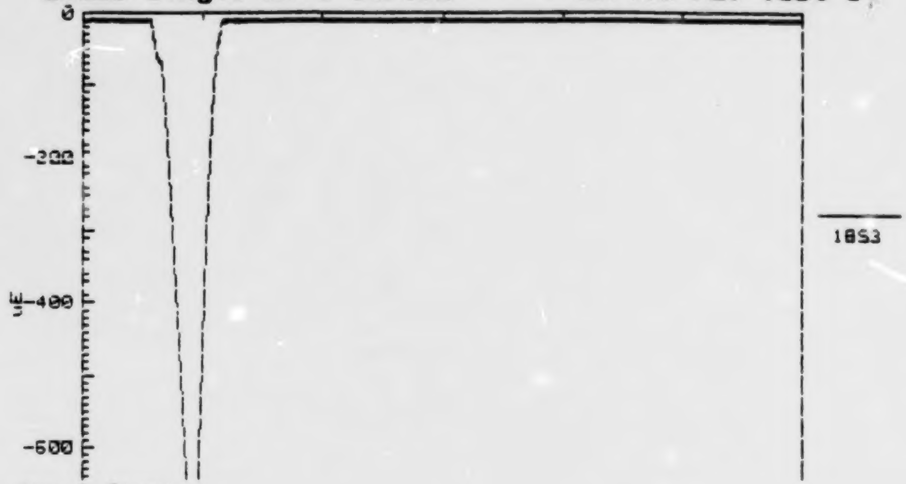
GEOTECHnical Resources Ltd. ANALYSIS DATE:10 May 1988

Actuator Displacement **Series PBT Test 3**



GEOTECHnical Resources Ltd.   ANALYSIS DATE:10 May 1988

Blade Single-Axis Strain   Series PBT Test 3

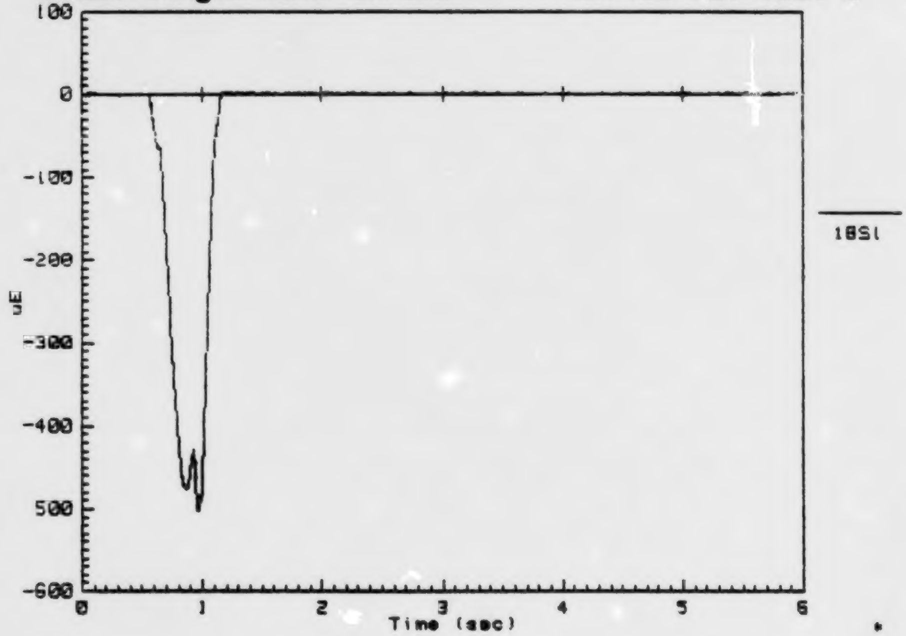


Menu 4: Plotting

[redacted]

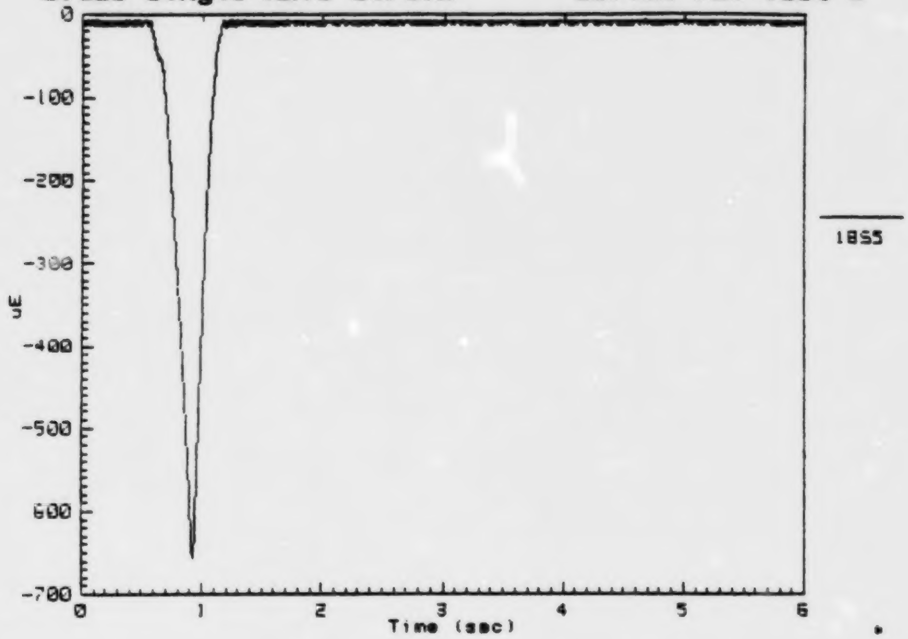
GEOTECHnical Resources Ltd.   ANALYSIS DATE:10 May 1988

Blade Single-Axis Strain   Series PBT Test 3



GEOTECHnical Resources Ltd.   ANALYSIS DATE:10 May 1988

Blade Single-Axis Strain   Series PBT Test 3



GEOTECHnical resources ltd
PROP BUSTERS
PROJECT NUMBER: 9448

```
Date: 10 May 1988
Time: 14:38:55

Test series...... PBT
Test number...... 4

*** Window 1 ***
Test duration .................. 6 Second(s)
AD-200 sample period........... 16.1 Micro-second(s)
Sample rate, aggregate ......... 62111 Hz.
Sample rate per channel ........ 3881 Hz.
Number of samples per channel .. 23292 words.
Total number of samples ........ 745344 words.
Trigger source ................. INTERNAL
Number of cards ................ 2
Number of channels per card .... 16
Total number of channels ....... 32
```

```
                               GEOTECHnical resources ltd
                                      PROP BUSTERS
                                 PROJECT NUMBER: 9448


Date: 10 May 1988
Time: 14:55:58

Test series...... PBT
Test number...... 4

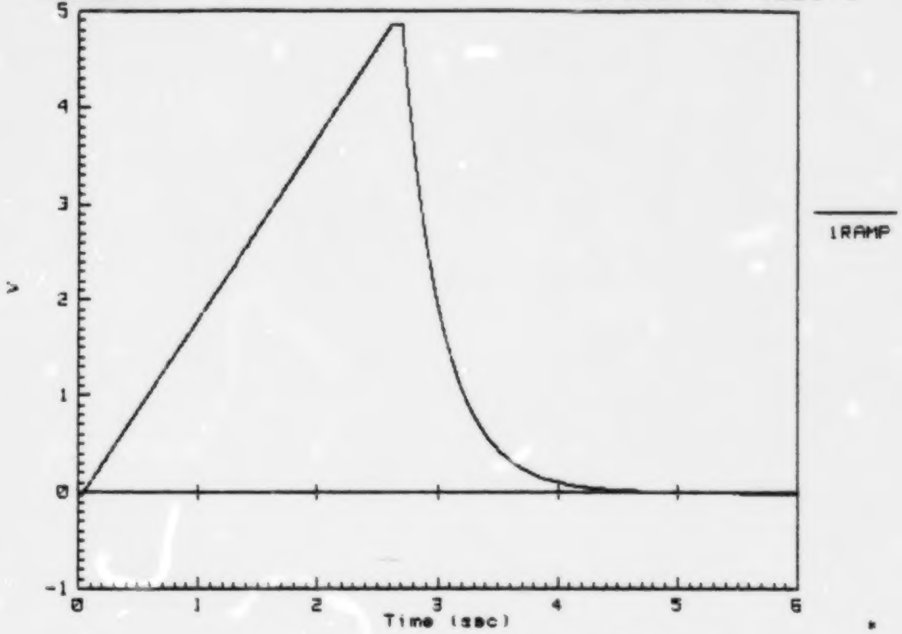
*** Window 1 ***
Test duration .................. 6 Second(s)
AD-200 sample period............ 16.1 Micro-second(s)
Sample rate, aggregate ......... 62111 Hz.
Sample rate per channel ........ 3881 Hz.
Number of samples per channel .. 23292 words.
Total number of samples ........ 745344 words.
Trigger source ................. INTERNAL
Number of cards ................ 2
Number of channels per card .... 16
Total number of channels ....... 32
```

Transducer table for test #PBT04_HDR

```
14690 Card1:!
14700    !-----!--!--!--!--!----!--------!--------!-------!------!---------!
14710    !Card !Ch!SW!HW!Ex!Mode!  Gain  ! Offset ! Units !  Ch  !  Serial !
14720    ! no. !no!gn!gn!gn!    !(eng/V)!  (V)   ! (/V)  !  Id  !  Number !
14730    !-----!--!--!--!--!----!--------!--------!-------!------!---------!
14740    DATA 1, 1, 1, 1, 1, "S",  107.29,  2.9028,   "mm", "BD1",  "A33380"
14750    DATA 1, 2, 1, 1, 1, "S",  107.42,  2.9517,   "mm", "BD2",  "A22090"
14760    DATA 1, 3, 1, 1, 1, "S",  107.42,  2.4609,   "mm", "BD3",  "A22091"
14770    DATA 1, 4, 1, 1, 1, "S",  6.8529,  0.0879,  "MPa","APR1",    "5817"
14780    DATA 1, 5, 1, 1, 1, "S",  6.8586,  0.0049,  "MPa","APE1",    "4986"
14790    DATA 1, 6, 1, 1, 1, "S",  6.8792,  0.0562,  "MPa","APR2",    "5723"
14800    DATA 1, 7, 1, 1, 1, "S",  6.8636,  0.0708,  "MPa","APE2",    "5815"
14810    DATA 1, 8, 1, 1, 1, "S",  6.8643,  0.0806,  "MPa","APR3",    "5883"
14820    DATA 1, 9, 1, 1, 1, "S",  6.8531,  0.0562,  "MPa","APE3",    "5885"
14830    DATA 1,10, 1, 1, 1, "S",  13.709,  0.0757,  "MPa", "BP1",    "5887"
14840    DATA 1,11, 1, 1, 1, "S",  13.712,  0.0000,  "MPa", "BP2",    "5773"
14850    DATA 1,12, 1, 1, 1, "S",  13.734,  0.0806,  "MPa", "BP3",    "5892"
14860    DATA 1,13, 1, 1, 1, "S",  13.731,  0.0708,  "MPa", "BP4",    "5889"
14870    DATA 1,14, 1, 1, 1, "S",  13.717,  0.0000,  "MPa", "BP5",    "5891"
14880    DATA 1,15, 1, 1, 2, "S",     1.0,       0,  "  V","RAMP",  "       "
14890    DATA 1,16, 1, 1, 1, "S",  1000.0,       0,   "uE","BR1B",  "       "
14900 Card2:!
14910    DATA 2, 1 ,1, 1, 2, "S",  53.906,  1.4160,   "mm", "AD1",  "A22091"
14920    DATA 2, 2, 1, 1, 2, "S",  53.634,  1.4014,   "mm", "AD2",  "A33381"
14930    DATA 2, 3, 1, 1, 2, "S",  53.608,  1.6895,   "mm", "AD3",  "A33382"
14940    DATA 2, 4, 1, 1, 1, "S",  1000.0,       0,   "uE","BRIA",  "       "
14950    DATA 2, 5, 1, 1, 1, "S",  1000.0,       0,   "uE","FSG2",  "       "
14960    DATA 2, 6, 1, 1, 1, "S",  1000.0,       0,   "uE","FSG3",  "       "
14970    DATA 2, 7, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS7",  "       "
14980    DATA 2, 8, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS8",  "       "
14990    DATA 2, 9, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS9",  "       "
15000    DATA 2,10, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS1",  "       "
15010    DATA 2,11, 1, 1, 1, "S",  1000.0,       0,   "uE","BR2B",  "       "
15020    DATA 2,12, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS3",  "       "
15030    DATA 2,13, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS4",  "       "
15040    DATA 2,14, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS5",  "       "
15050    DATA 2,15, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS6",  "       "
15060    DATA 2,16, 1, 1, 1, "S",  1000.0,       0,   "uE","BRIC",  "       "
15070    !-----!--!--!--!--!----!--------!--------!-------!------!---------!
15080    !Card !Ch!SW!HW!Ex!Mode!  Gain  ! Offset ! Units !  Ch  !  Serial !
15090    ! no. !no!gn!gn!gn!    !(Eng/V)!  (V)   ! (/V)  !  Id  !  Number !
15100    !-----!--!--!--!--!----!--------!--------!-------!------!---------!
15110 End_transducers:!
```

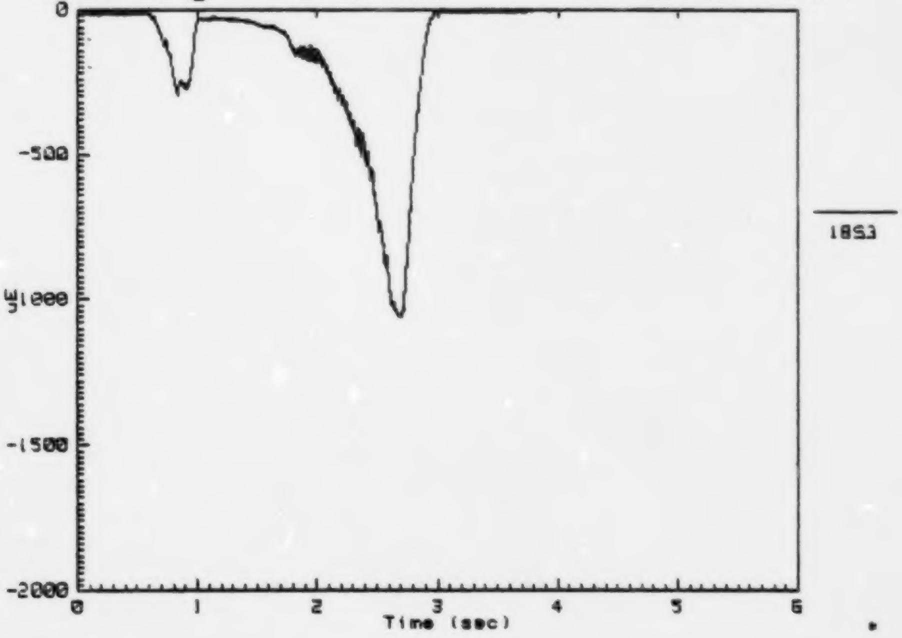
GEOTECHnical Resources Ltd. ANALYSIS DATE: 10 May 1988

Command **Series PBT Test 4**



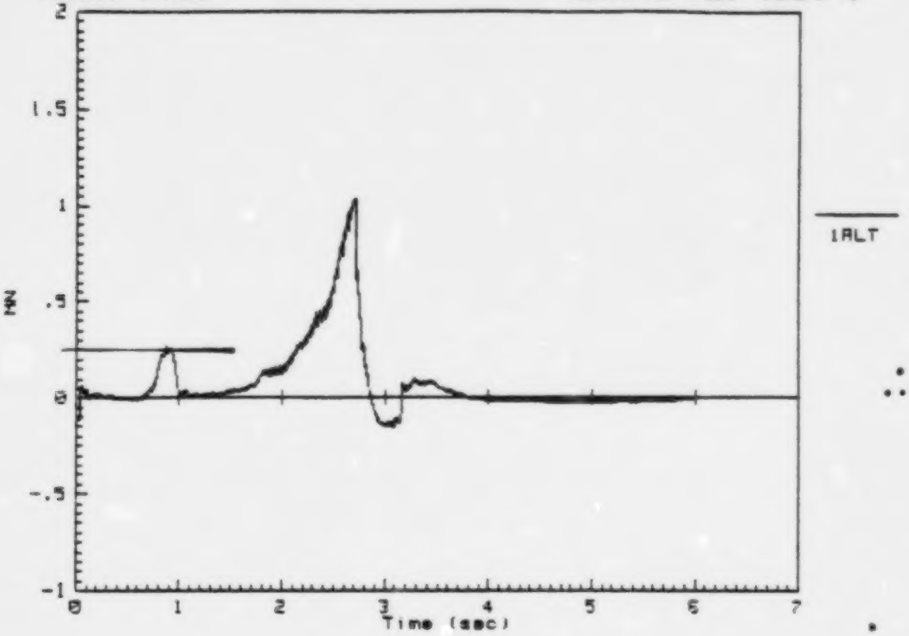
GEOTECHnical Resources Ltd. ANALYSIS DATE: 10 May 1988

Blade Single-Axis Strain **Series PBT Test 4**



GEOTECHnical Resources Ltd.   ANALYSIS DATE: 10 May 1988

Total Load   **Series PBT Test 4**



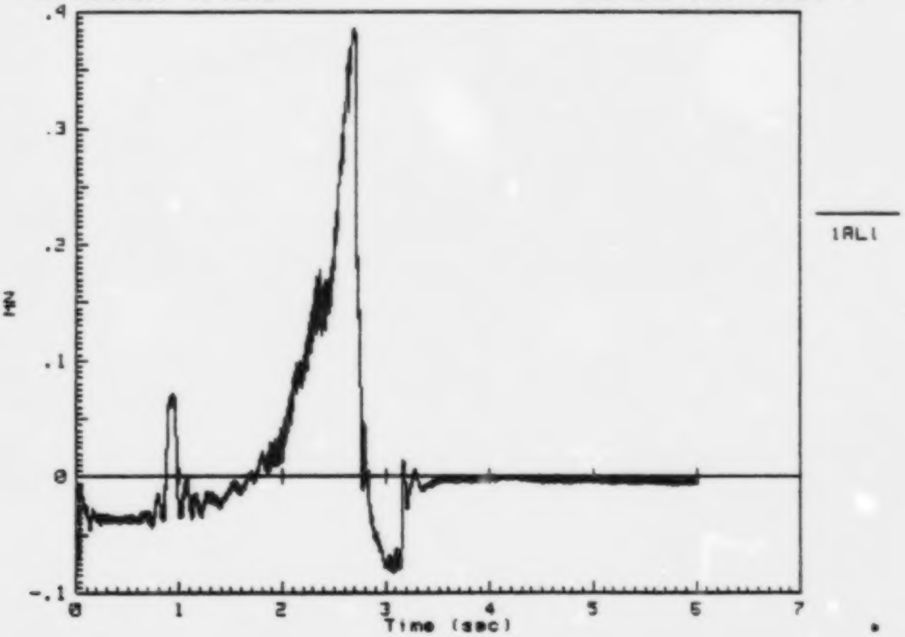
peak load 0.25MN

area = $0.68m^2$

∴ strength = 0.37MPa

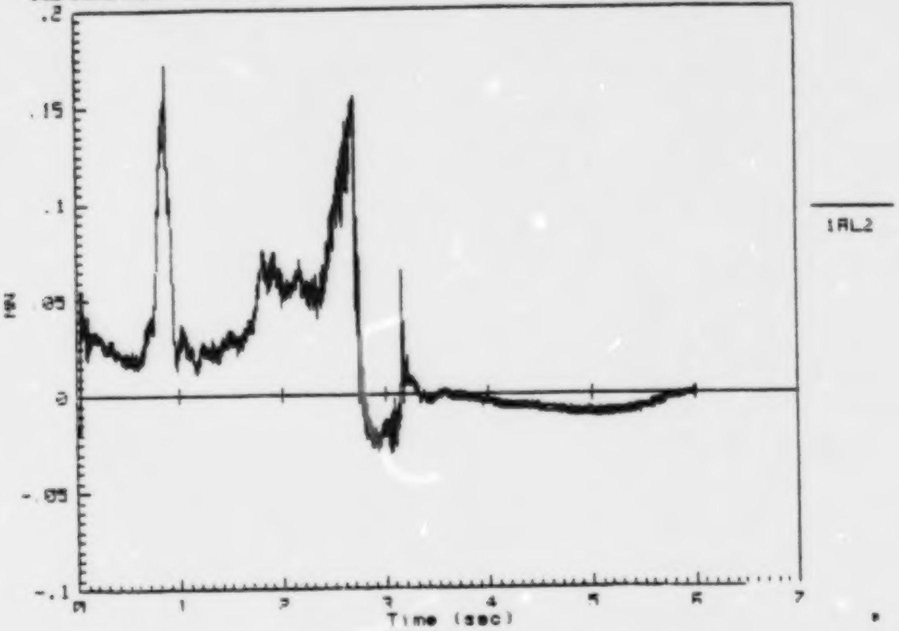
GEOTECHnical Resources Ltd.   ANALYSIS DATE: 10 May 1988

Actuator 1 Load   **Series PBT Test 4**



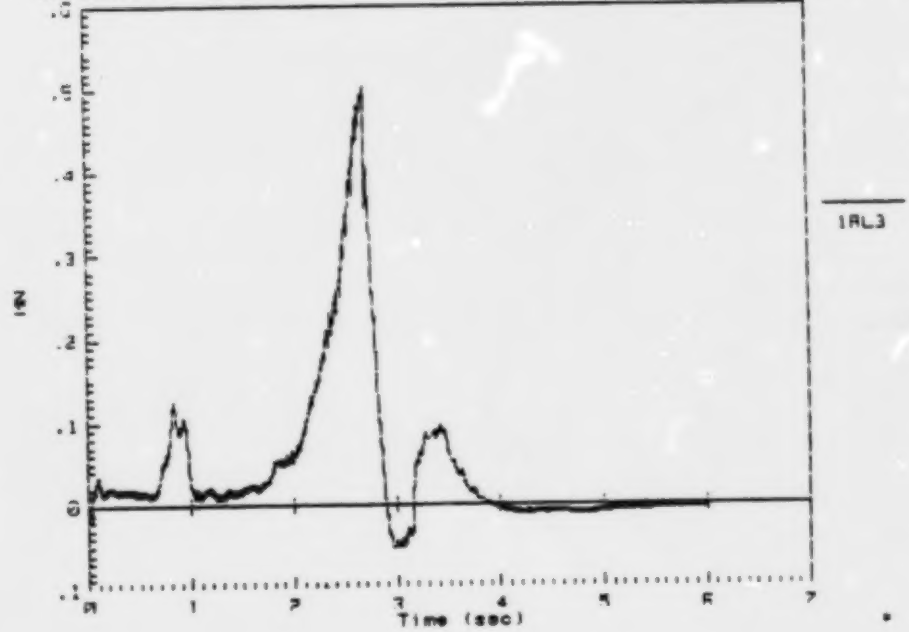
GEOTECHnical Resources Ltd. ANALYSIS DATE:10 May 1988

Actuator 2 Load **Series PBT Test 4**



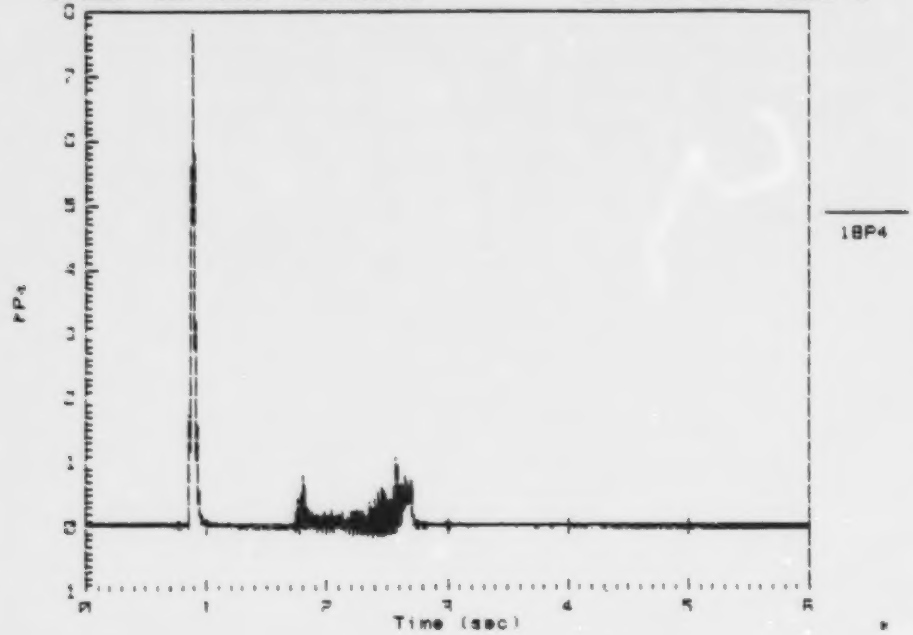
GEOTECHnical Resources Ltd. ANALYSIS DATE:10 May 1988

Actuator 3 Load **Series PBT Test 4**



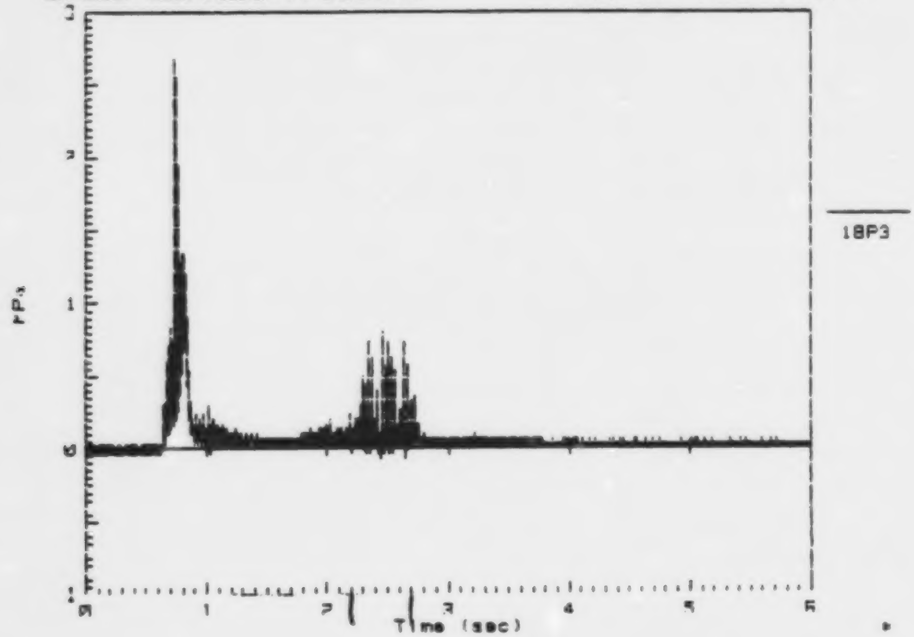
GEOTECHnical Resources Ltd.   ANALYSIS DATE: 10 May 1988

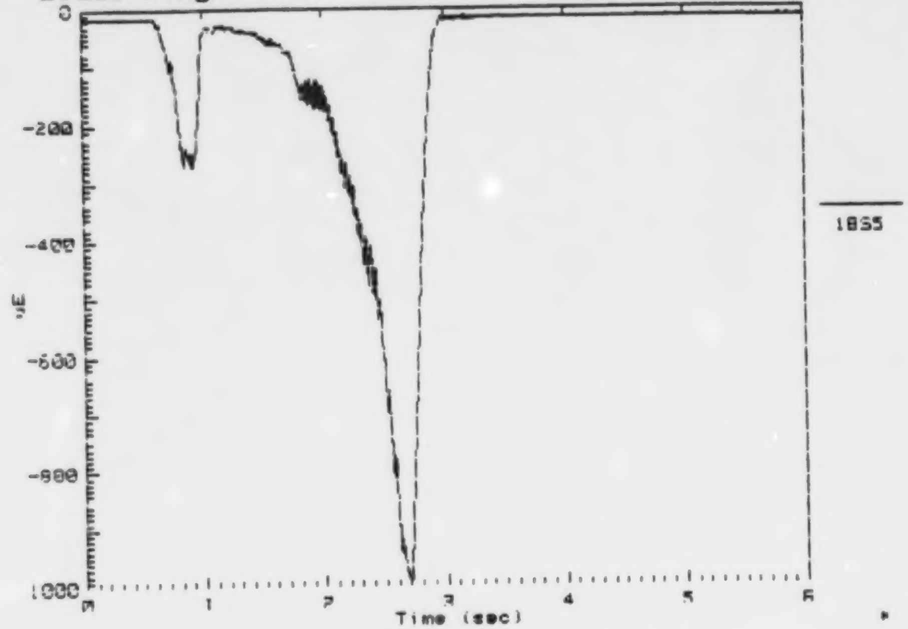
Blade Surface Pressure   **Series PDT Test 4**



GEOTECHnical Resources Ltd.   ANALYSIS DATE: 10 May 1988

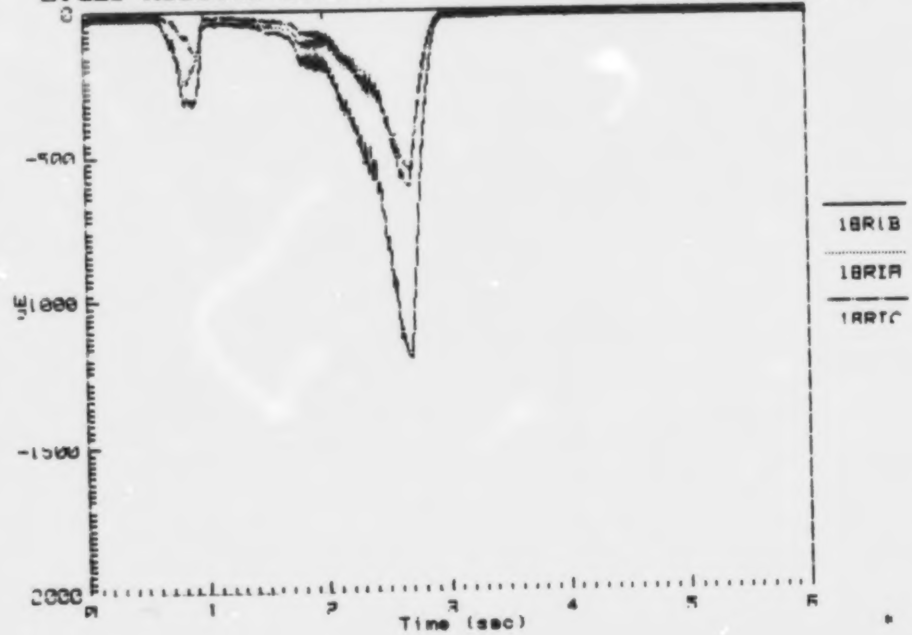
Blade Surface Pressure   **Series PDT Test 4**





GEOTECHnical Resources Ltd. ANALYSIS DATE: 10 May 1988

Blade Single Axis Strain **Series MDT Test 4**

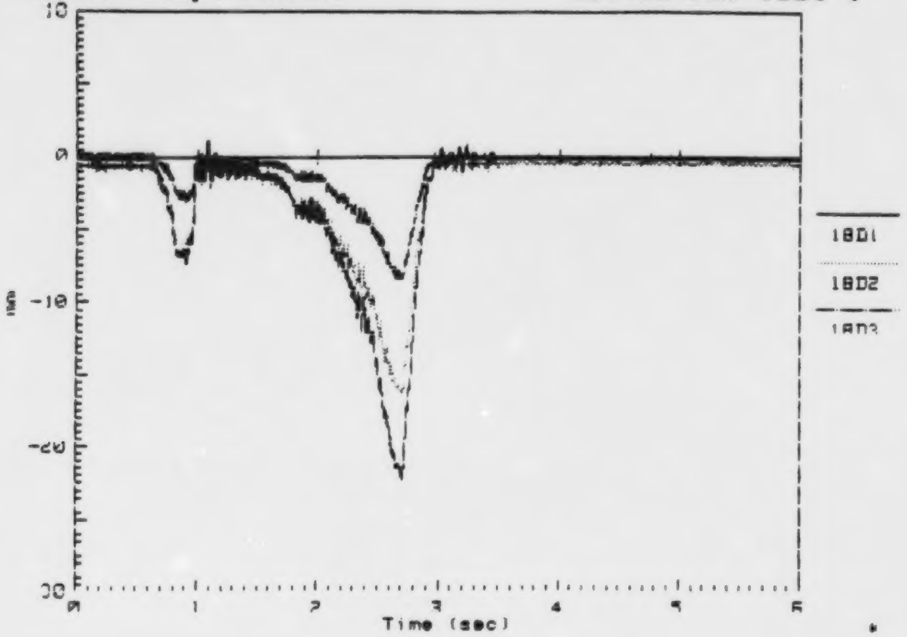


GEOTECHnical Resources Ltd. ANALYSIS DATE: 10 May 1988

Blade Rosette Strain **Series MDT Test 4**

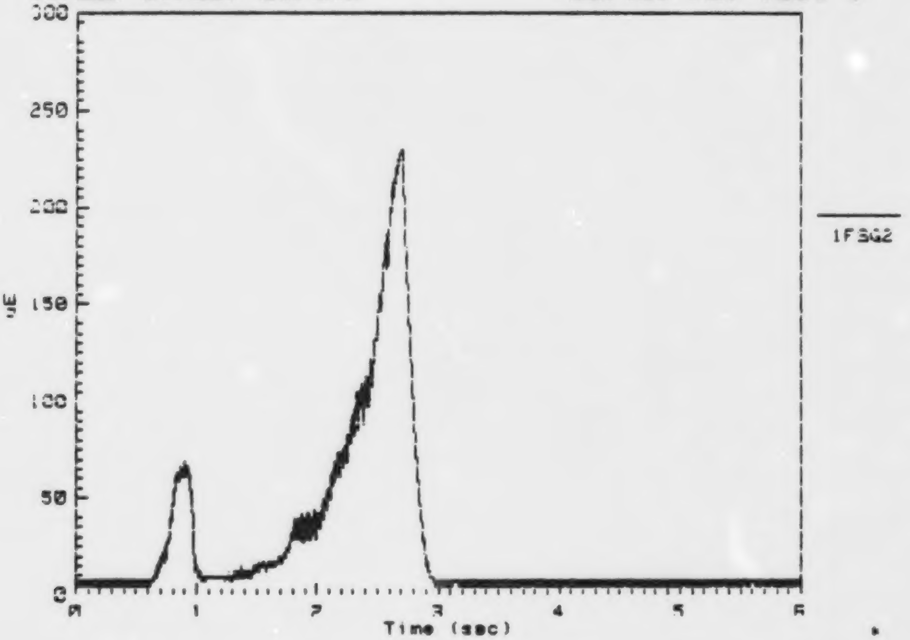
GEOTECHnical Resources Ltd.   ANALYSIS DATE: 18 May 1988

Blade Displacement   **Series FDT Test 4**



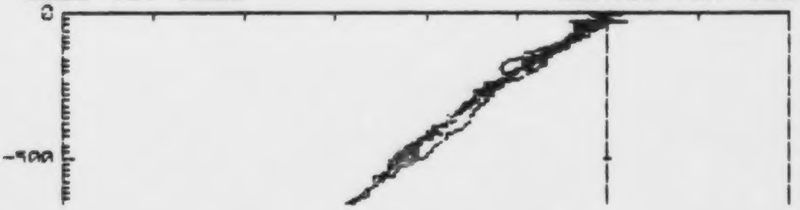
GEOTECHnical Resources Ltd.   ANALYSIS DATE: 18 May 1988

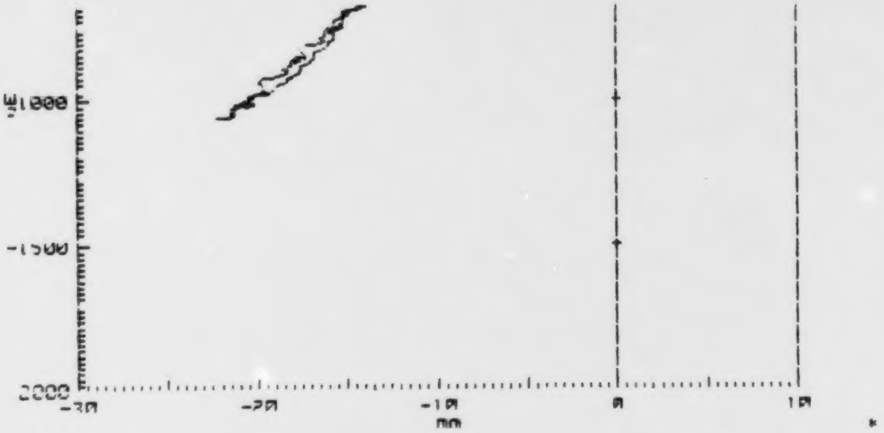
Frame Girder Strain   **Series FDT Test 4**



GEOTECHnical Resources Ltd.   ANALYSIS DATE: 18 May 1988

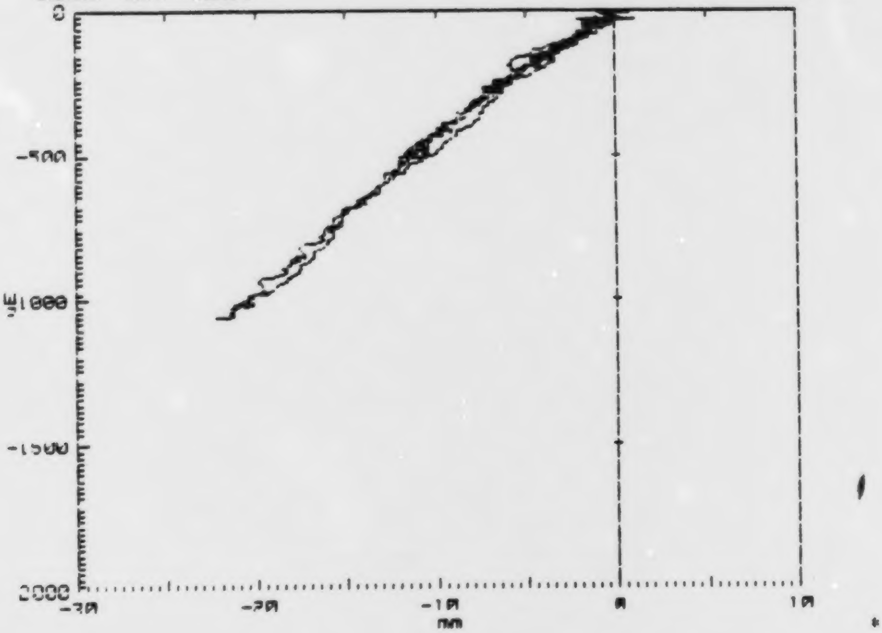
1BG3 vs. 1BD1   **Series FDT Test 4**





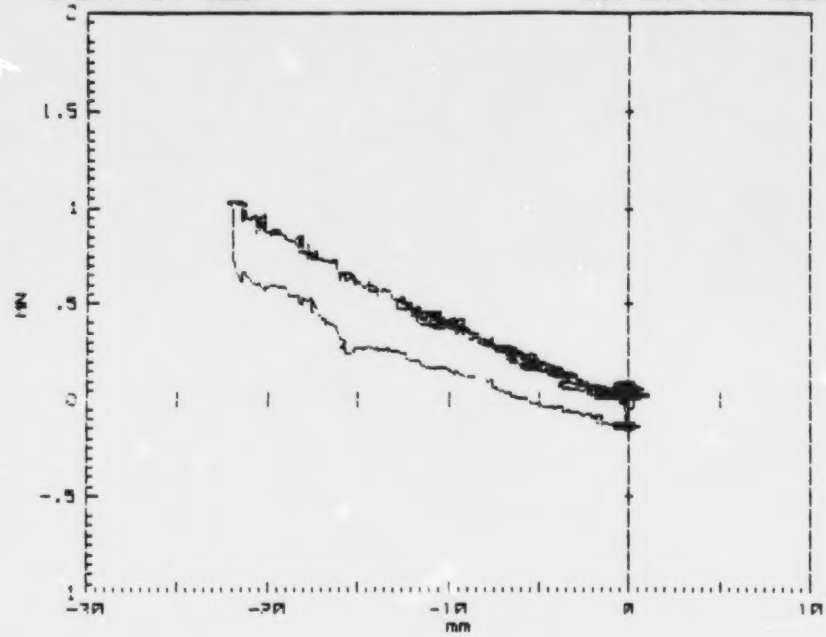
GEOTECHnical Resources Ltd.   ANALYSIS DATE:10 May 1988

1DC3 vs. 1DD1   **Series PDT Test 4**



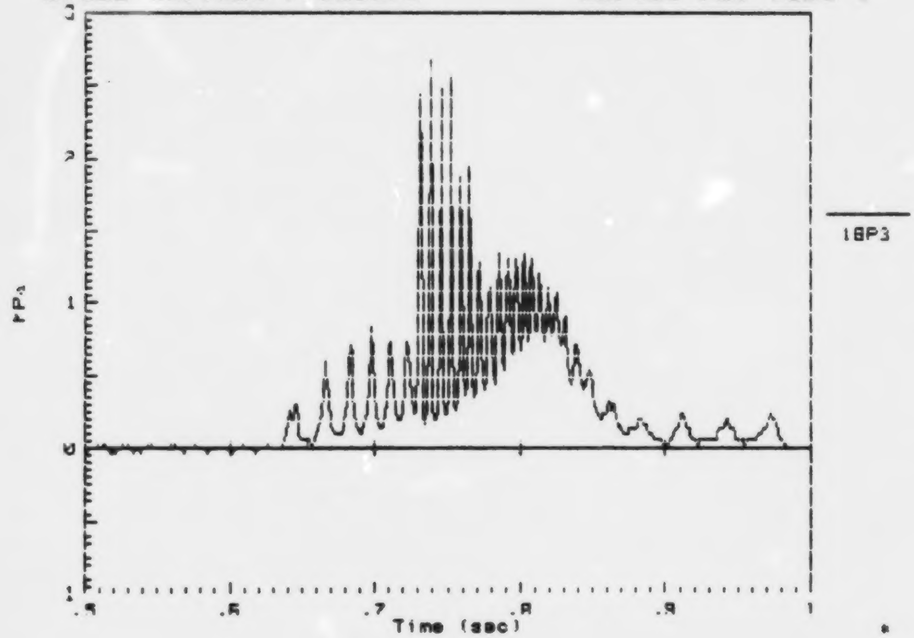
GEOTECHnical Resources Ltd.   ANALYSIS DATE: 10 May 1988

1MLT vs. 1DD1   **Series PDT Test 4**



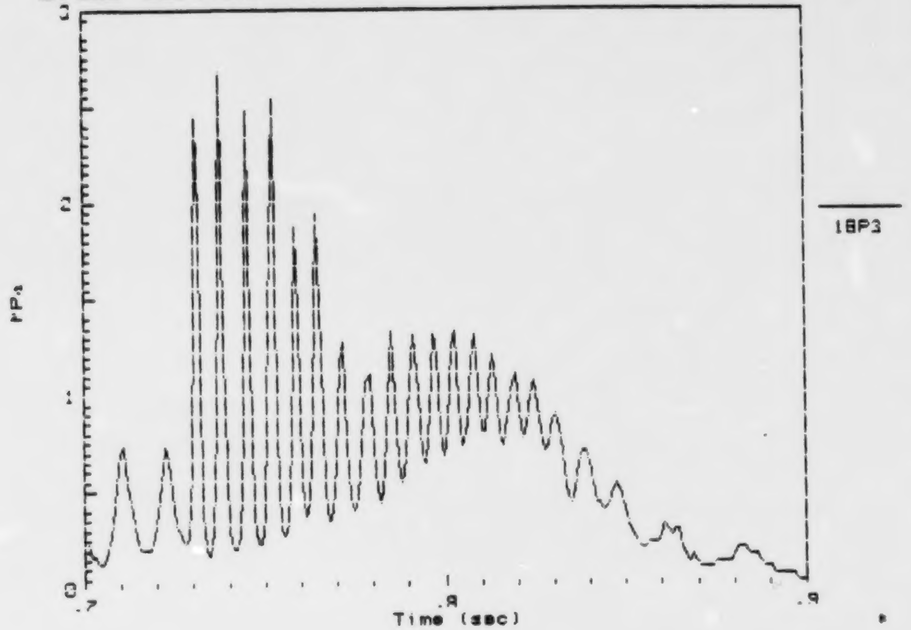
GEOTECHnical Resources Ltd.   ANALYSIS DATE: 10 May 1988

Blade Surface Pressure   **Series PDT Test 4**



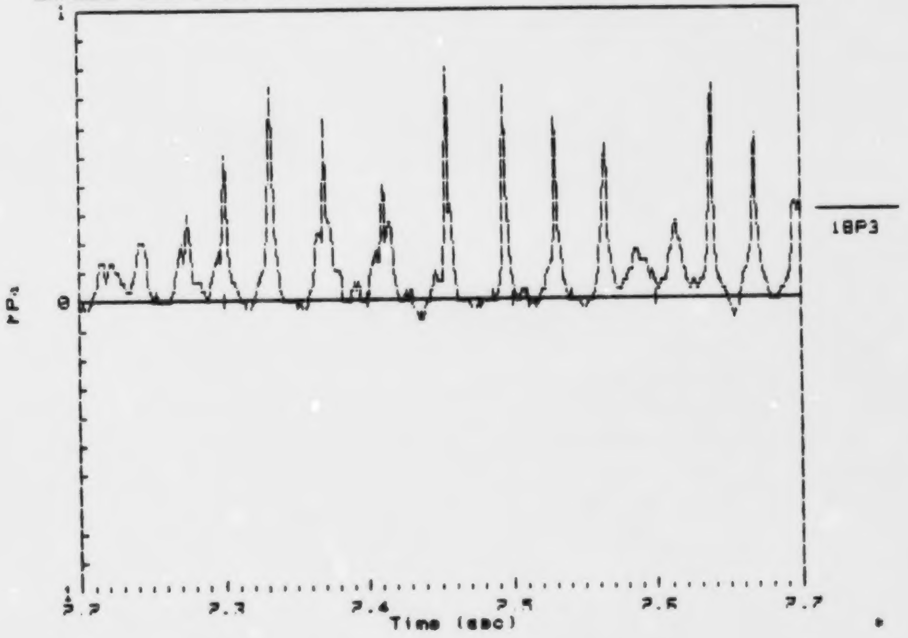
GEOTECHnical Resources Ltd. ANALYSIS DATE: 10 May 1988

Blade Surface Pressure **Series PDT Test 4**



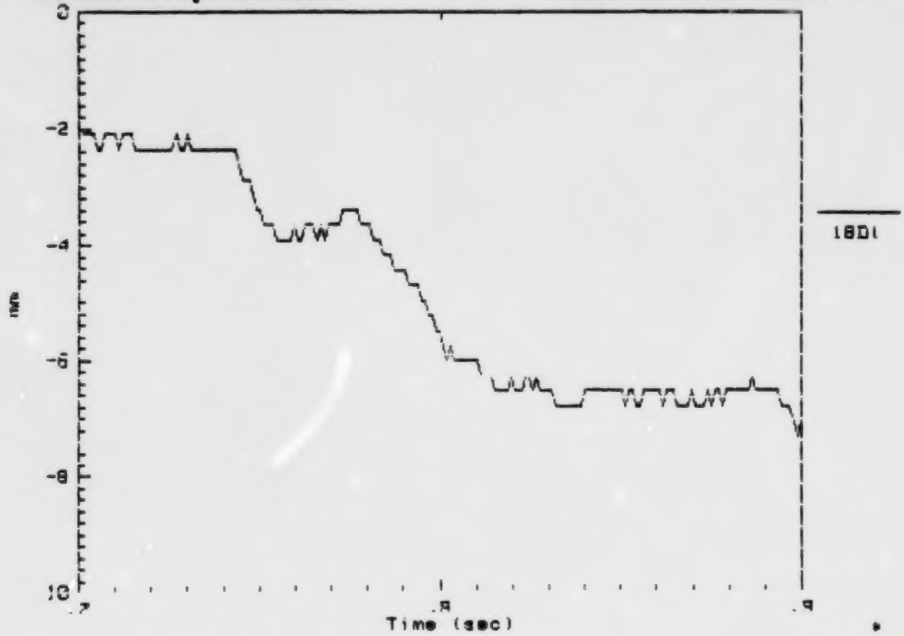
GEOTECHnical Resources Ltd. ANALYSIS DATE: 10 May 1988

Blade Surface Pressure **Series PDT Test 4**



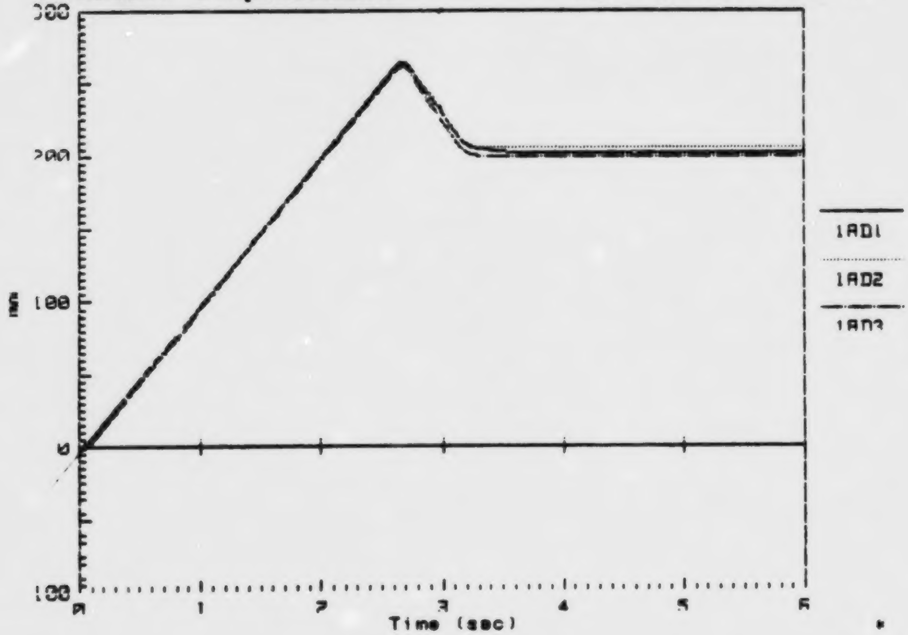
GEOTECHnical Resources Ltd. ANALYSIS DATE: 10 May 1988

Blade Displacement **Series PDT Test 4**



GEOTECHnical Resources Ltd. ANALYSIS DATE: 10 May 1988

Actuator Displacement **Series PDT Test 4**



```
                      GEOTECHnical resources ltd
                             PROP BUSTERS
                        PROJECT NUMBER: 9448


Date: 11 May 1988
Time: 11:44:24

Test series...... PBT
Test number...... 5

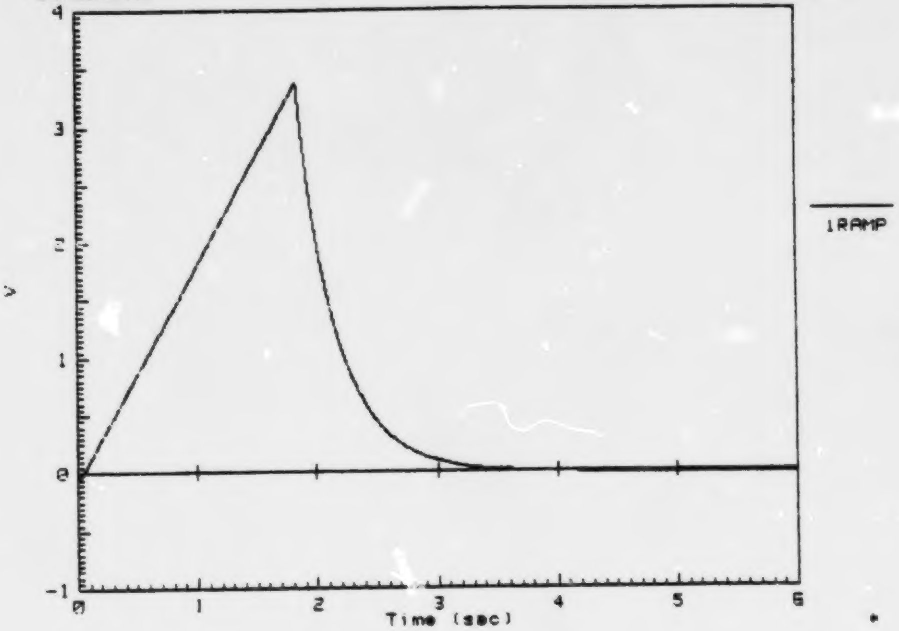
*** Window 1 ***
Test duration .................. 6 Second(s)
AD-200 sample period............ 16.1 Micro-second(s)
Sample rate, aggregate ......... 62111 Hz.
Sample rate per channel ........ 3881 Hz.
Number of samples per channel .. 23292 words.
Total number of samples ........ 745344 words.
Trigger source ................. INTERNAL
Number of cards ................ 2
Number of channels per card .... 16
Total number of channels ....... 32
```

```
Transducer table for test #PBT05_HDR

14690 Card1:!
14700    !-----|--|--|--|--|----|--------|--------|-------|------|---------|
14710    !Card |Ch|SW|HW|Ex|Mode|  Gain  | Offset | Units |  Ch  |  Serial |
14720    ! no. |no|gn|gn|gn|    | (eng/V)|  (V)   | (/V)  |  Id  |  Number |
14730    !-----|--|--|--|--|----|--------|--------|-------|------|---------|
14740    DATA 1, 1, 1, 1, 1, "S",  107.29,  2.9028,   "mm", "BD1",  "A33380"
14750    DATA 1, 2, 1, 1, 1, "S",  107.42,  2.9517,   "mm", "BD2",  "A22090"
14760    DATA 1, 3, 1, 1, 1, "S",  107.42,  2.4609,   "mm", "BD3",  "A22091"
14770    DATA 1, 4, 1, 1, 1, "S",  6.8529,  0.0879,  "MPa","APR1",    "5817"
14780    DATA 1, 5, 1, 1, 1, "S",  6.8586,  0.0049,  "MPa","APE1",    "4986"
14790    DATA 1, 6, 1, 1, 1, "S",  6.8792,  0.0562,  "MPa","APR2",    "5723"
14800    DATA 1, 7, 1, 1, 1, "S",  6.8636,  0.0708,  "MPa","APE2",    "5815"
14810    DATA 1, 8, 1, 1, 1, "S",  6.8643,  0.0806,  "MPa","APR3",    "5883"
14820    DATA 1, 9, 1, 1, 1, "S",  6.8531,  0.0562,  "MPa","APE3",    "5885"
14830    DATA 1,10, 1, 1, 1, "S",  13.709,  0.0757,  "MPa", "BP1",    "5887"
14840    DATA 1,11, 1, 1, 1, "S",    1000,  0.0000,   "uE","BR2A",  "      "
14850    DATA 1,12, 1, 1, 1, "S",  13.734,  0.0806,  "MPa", "BP3",    "5892"
14860    DATA 1,13, 1, 1, 1, "S",  13.731,  0.0708,  "MPa", "BP4",    "5889"
14870    DATA 1,14, 1, 1, 1, "S",    1000,  0.0000,  "MPa","BR2C",  "      "
14880    DATA 1,15, 1, 1, 2, "S",     1.0,       0,  "  V","RAMP",  "      "
14890    DATA 1,16, 1, 1, 1, "S",  1000.0,       0,   "uE","BR1B",  "      "
14900 Card2:!
14910    DATA 2, 1 ,1, 1, 2, "S",  53.906,  1.4160,   "mm", "AD1",  "A22091"
14920    DATA 2, 2, 1, 1, 2, "S",  53.634,  1.4014,   "mm", "AD2",  "A33381"
14930    DATA 2, 3, 1, 1, 2, "S",  53.608,  1.6895,   "mm", "AD3",  "A33382"
14940    DATA 2, 4, 1, 1, 1, "S",  1000.0,       0,   "uE","BR1A",  "      "
14950    DATA 2, 5, 1, 1, 1, "S",  1000.0,       0,   "uE","FSG2",  "      "
14960    DATA 2, 6, 1, 1, 1, "S",  1000.0,       0,   "uE","FSG3",  "      "
14970    DATA 2, 7, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS7",  "      "
14980    DATA 2, 8, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS8",  "      "
14990    DATA 2, 9, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS9",  "      "
15000    DATA 2,10, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS1",  "      "
15010    DATA 2,11, 1, 1, 1, "S",  1000.0,       0,   "uE","BR2B",  "      "
15020    DATA 2,12, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS3",  "      "
15030    DATA 2,13, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS4",  "      "
15040    DATA 2,14, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS5",  "      "
15050    DATA 2,15, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS6",  "      "
15060    DATA 2,16, 1, 1, 1, "S",  1000.0,       0,   "uE","BR1C",  "      "
15070    !-----|--|--|--|--|----|--------|--------|-------|------|---------|
15080    !Card |Ch|SW|HW|Ex|Mode|  Gain  | Offset | Units |  Ch  |  Serial |
15090    ! no. |no|gn|gn|gn|    | (Eng/V)|  (V)   | (/V)  |  Id  |  Number |
15100    !-----|--|--|--|--|----|--------|--------|-------|------|---------|
15110 End_transducers:!
```

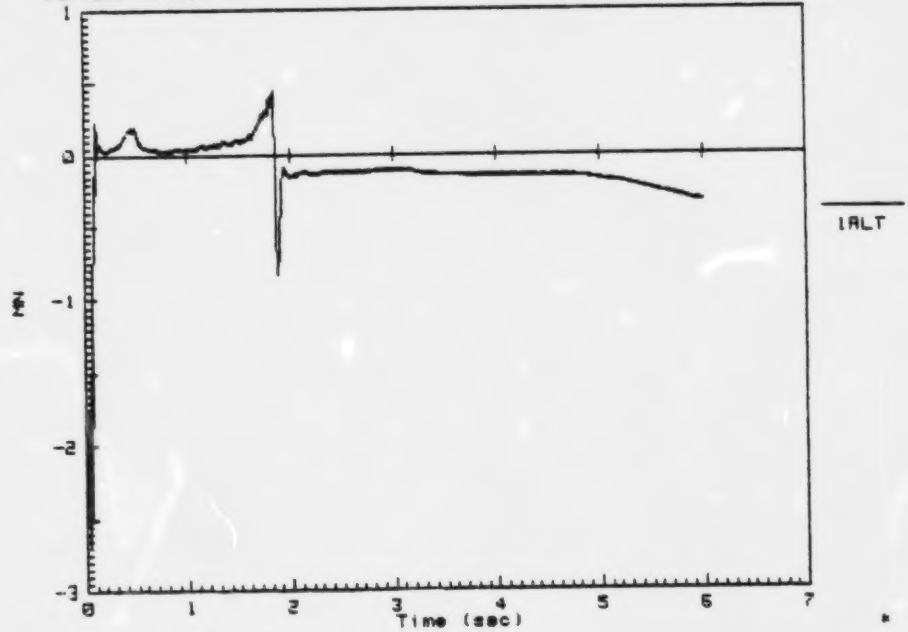
GEOTECHnical Resources Ltd. ANALYSIS DATE:11 May 1988

Command **Series PBT Test 5**



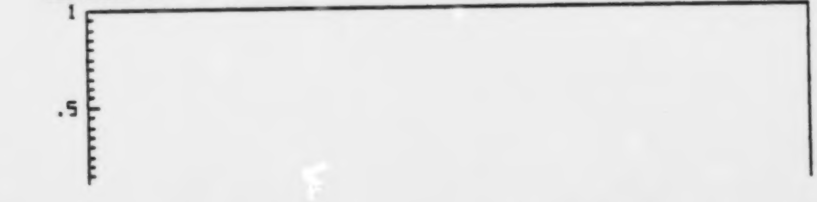
GEOTECHnical Resources Ltd. ANALYSIS DATE:11 May 1988

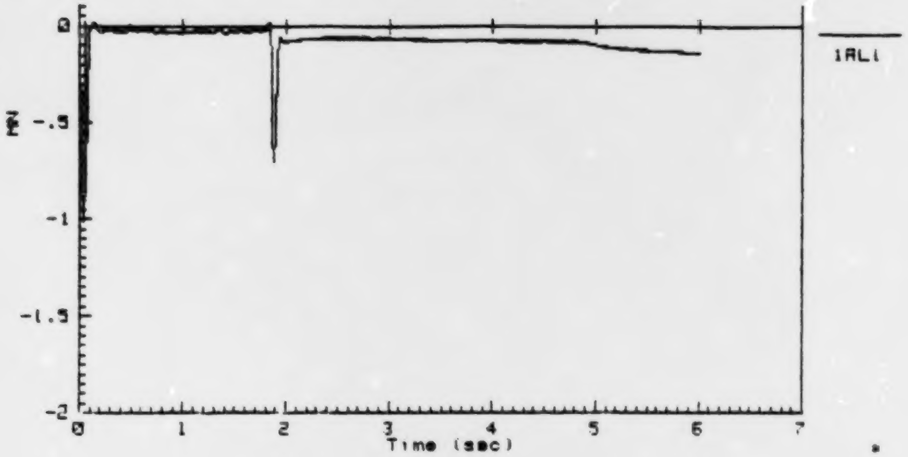
Total Load **Series PBT Test 5**



GEOTECHnical Resources Ltd. ANALYSIS DATE:11 May 1988

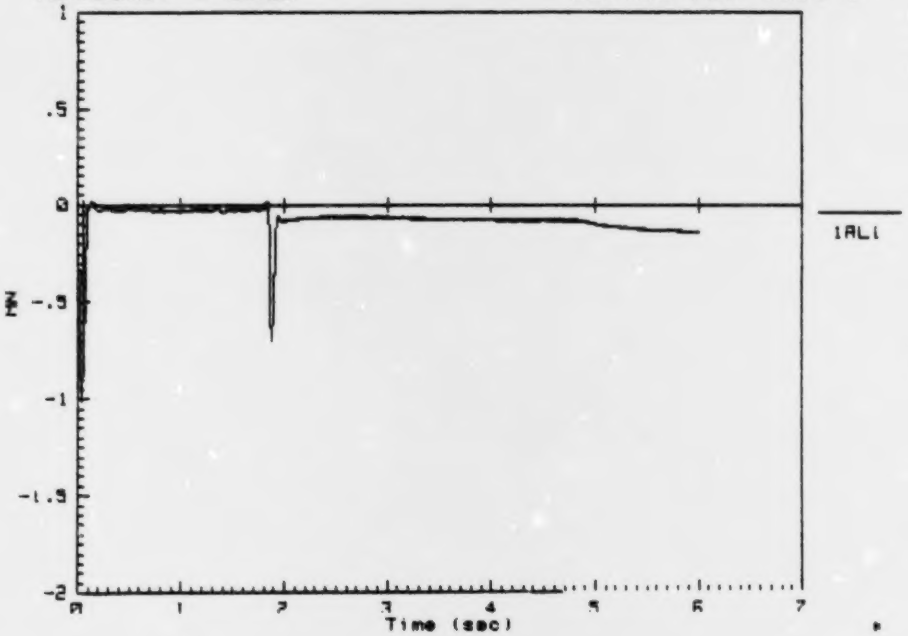
Actuator 1 Load **Series PBT Test 5**





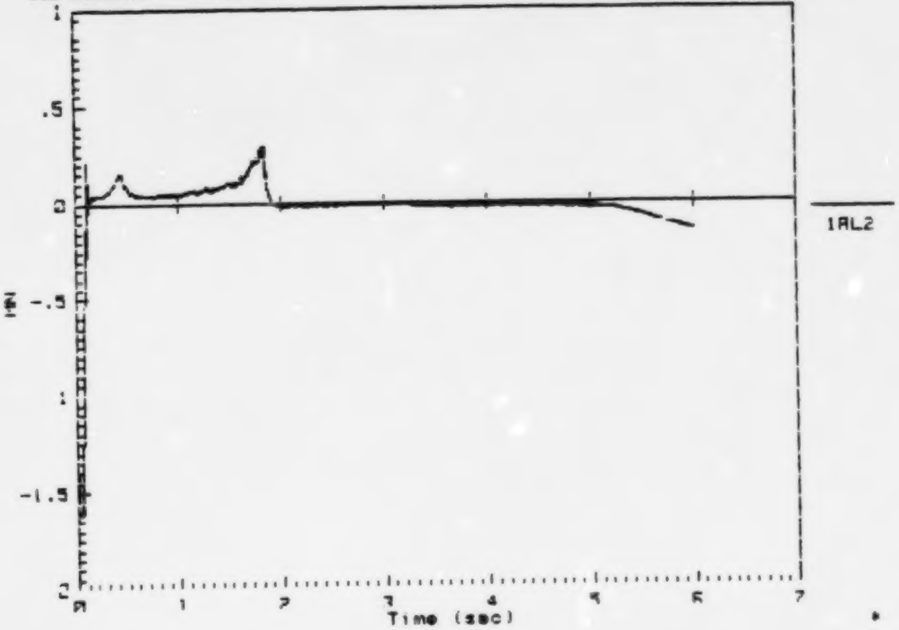
GEOTECHnical Resources Ltd. ANALYSIS DATE: 11 May 1988

Actuator 1 Load **Series PBT Test 5**



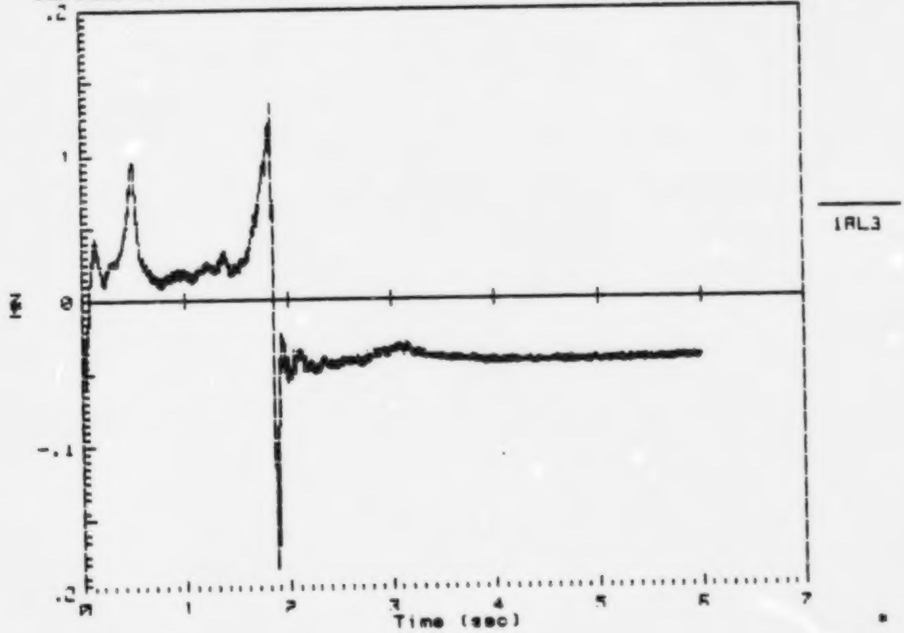
GEOTECHnical Resources Ltd. ANALYSIS DATE:11 May 1988

Actuator 2 Load **Series PDT Test 5**



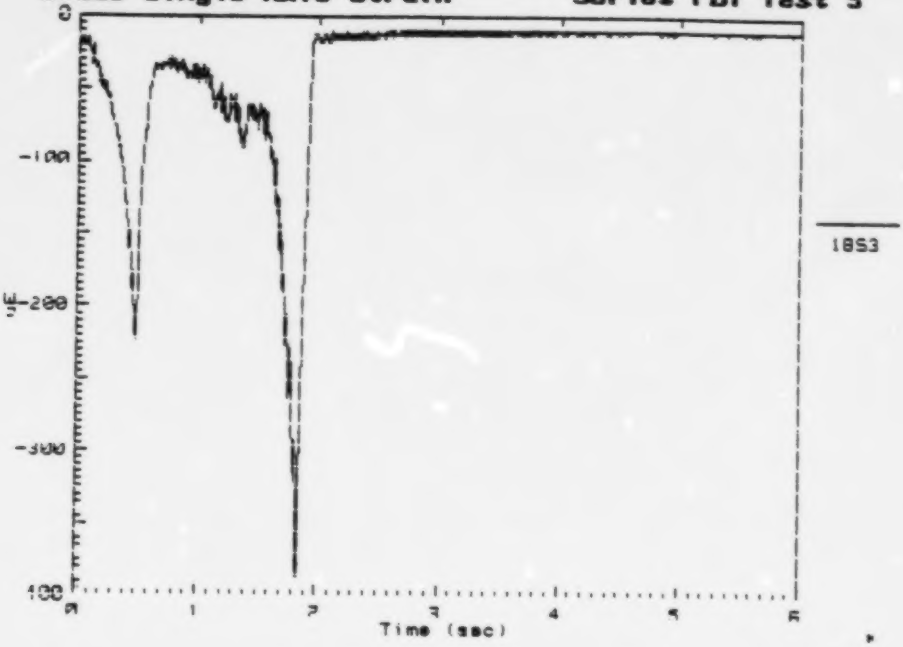
GEOTECHnical Resources Ltd. ANALYSIS DATE:11 May 1988

Actuator 3 Load **Series PDT Test 5**



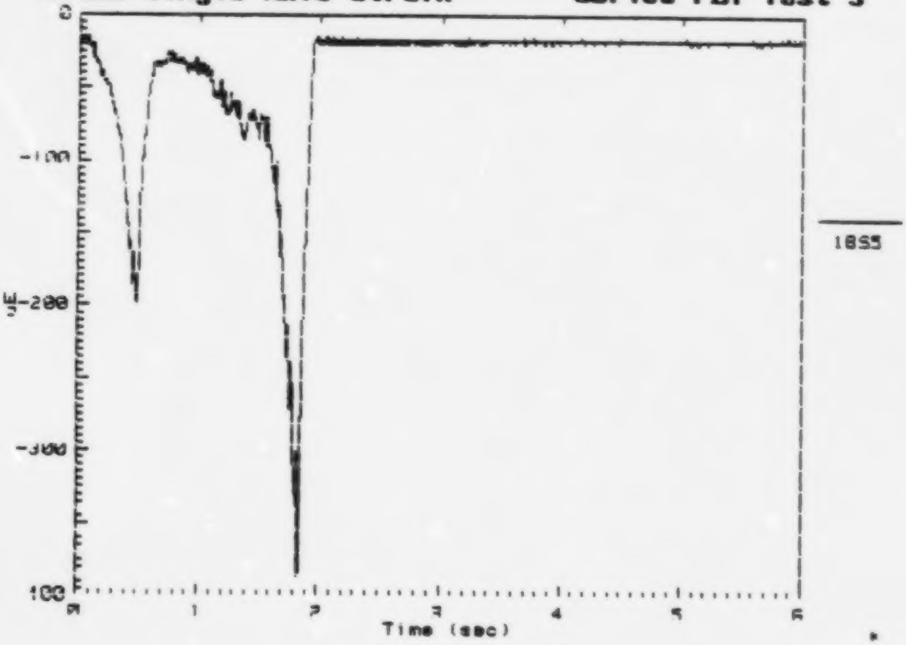
GEOTECHnical Resources Ltd.   ANALYSIS DATE: 11 May 1988

Blade Single Axis Strain   **Series MDT Test 5**



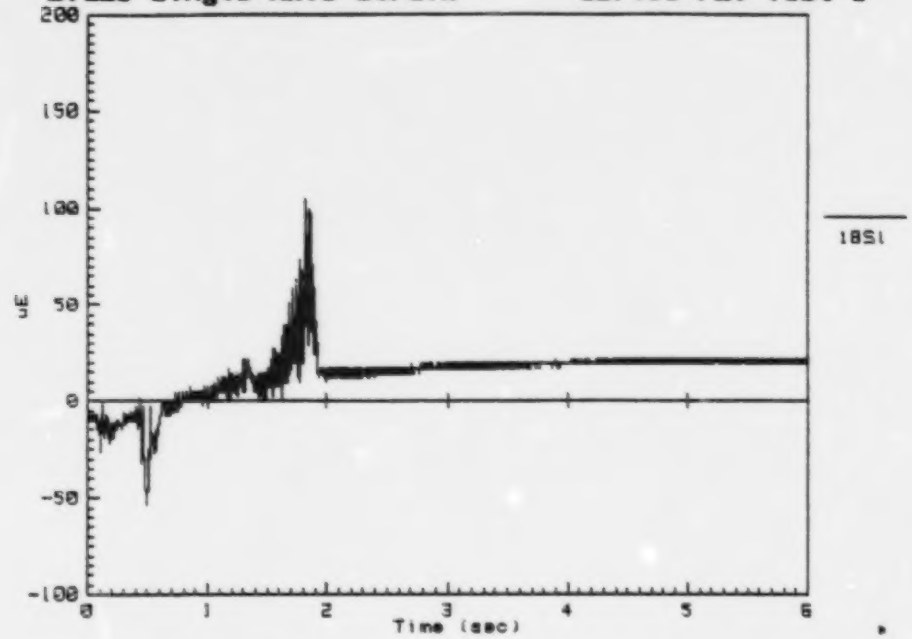
GEOTECHnical Resources Ltd.   ANALYSIS DATE: 11 May 1988

Blade Single Axis Strain   **Series MDT Test 5**



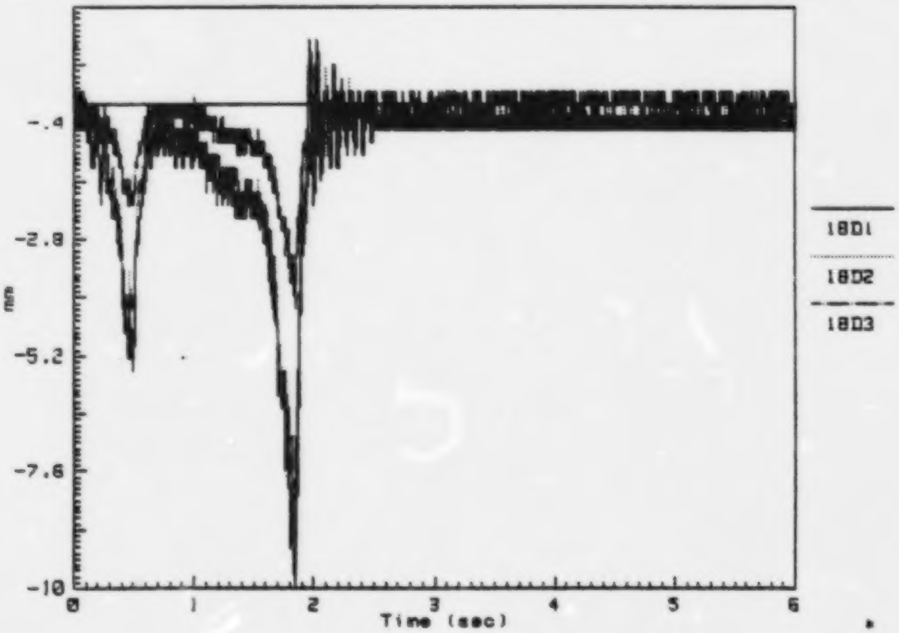
GEOTECHnical Resources Ltd.   ANALYSIS DATE:11 May 1988

Blade Single-Axis Strain   **Series PBT Test 5**



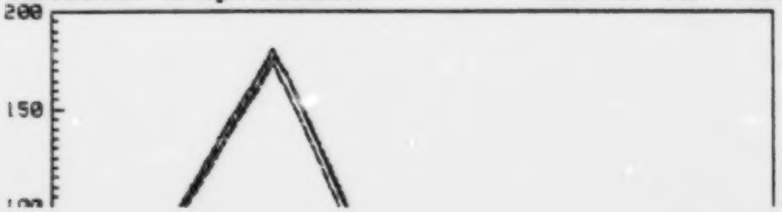
GEOTECHnical Resources Ltd.   ANALYSIS DATE:11 May 1988

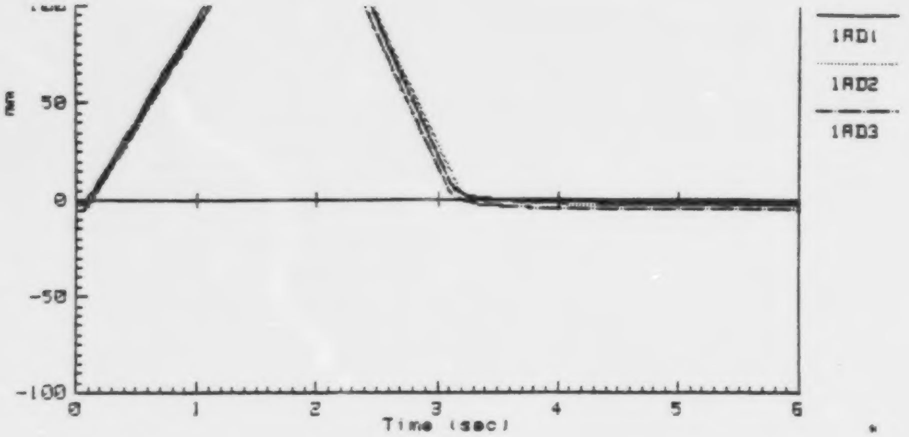
Blade Displacement   **Series PBT Test 5**



GEOTECHnical Resources Ltd.   ANALYSIS DATE:11 May 1988

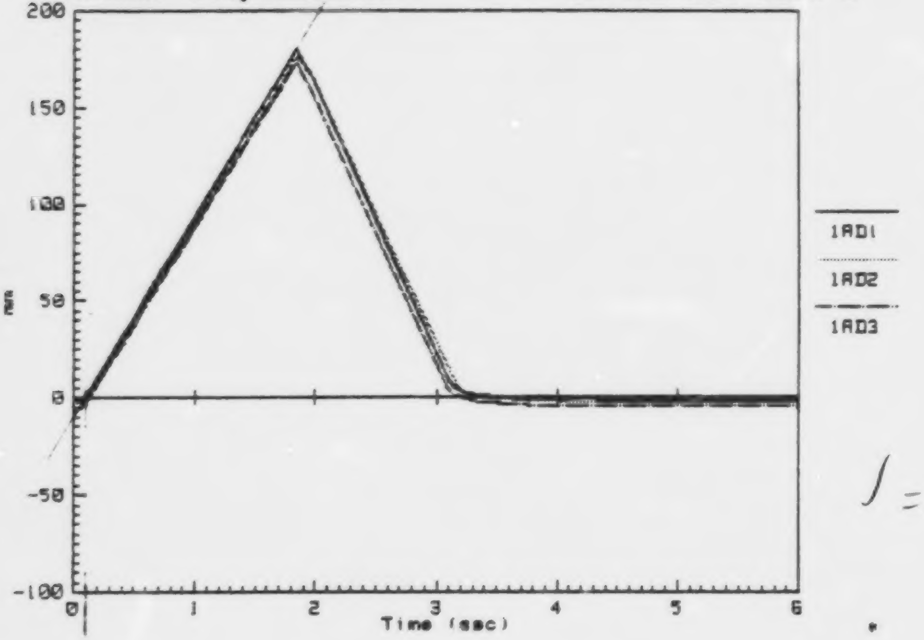
Actuator Displacement   **Series PBT Test 5**





GEOTECHnical Resources Ltd. ANALYSIS DATE:11 May 1988

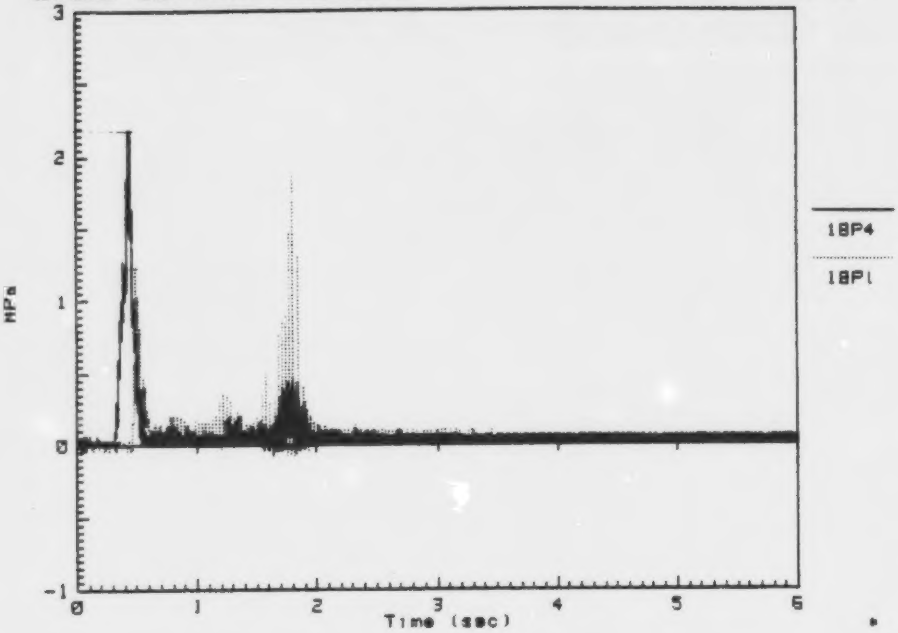
Actuator Displacement **Series PBT Test 5**



$\int = \frac{235 \text{ mm}}{2. - 0.15}$. [illegible] mm

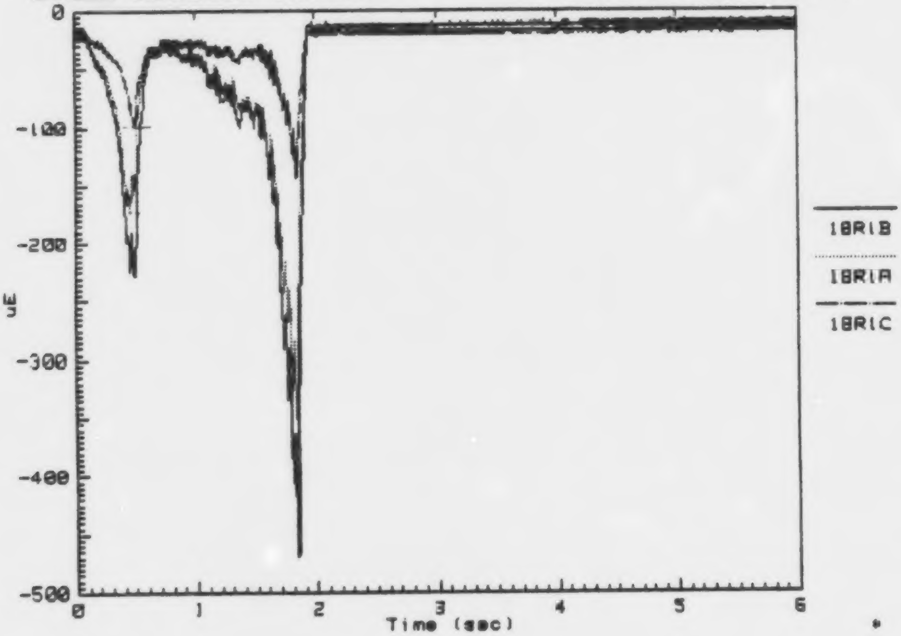
GEOTECHnical Resources Ltd. ANALYSIS DATE: 11 May 1988

Blade Surface Pressure **Series PBT Test 5**



GEOTECHnical Resources Ltd. ANALYSIS DATE: 11 May 1988

Blade Rosette Strain **Series PBT Test 5**



GEOTECHnical resources ltd
PROP BUSTERS
PROJECT NUMBER: 9448

```
Date: 11 May 1988
Time: 13:48:35

Test series...... PBT
Test number...... 6

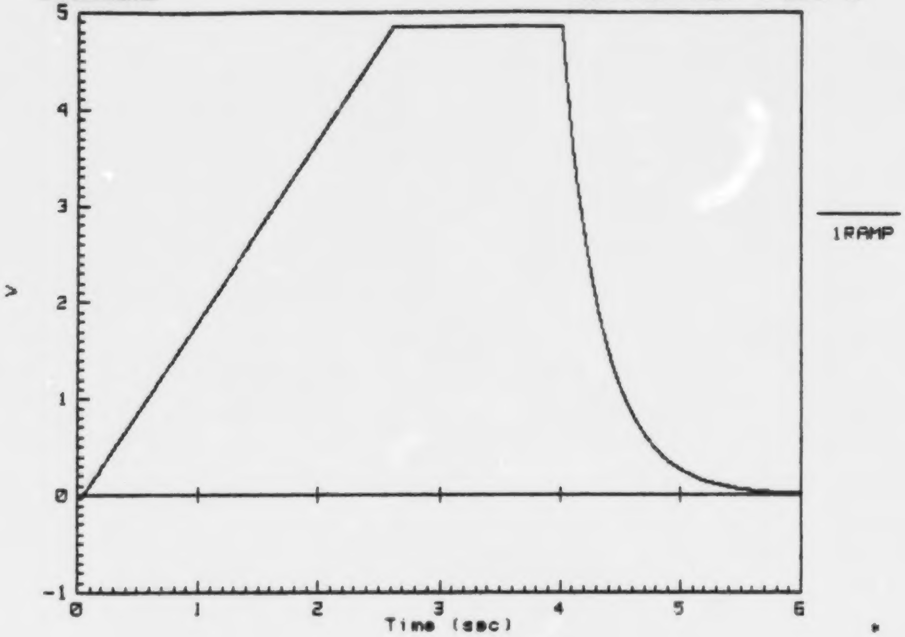
*** Window 1 ***
Test duration .................. 6 Second(s)
AD-200 sample period............ 16.1 Micro-second(s)
Sample rate, aggregate ......... 62111 Hz.
Sample rate per channel ........ 3881 Hz.
Number of samples per channel .. 23292 words.
Total number of samples ........ 745344 words.
Trigger source ................. INTERNAL
Number of cards ................ 2
Number of channels per card .... 16
Total number of channels ....... 32
```

```
Transducer table for test #PBT06_HDR

14690 Card1:!
14700    !-----¦--¦--¦--¦--¦----¦--------¦--------¦-------¦------¦---------¦
14710    !Card ¦Ch¦SW¦HW¦Ex¦Mode¦  Gain  ¦ Offset ¦ Units ¦  Ch  ¦  Serial ¦
14720    ! no. ¦no¦gn¦gn¦gn¦    ¦ (eng/V)¦  (V)   ¦ (/V)  ¦  Id  ¦  Number ¦
14730    !-----¦--¦--¦--¦--¦----¦--------¦--------¦-------¦------¦---------¦
14740    DATA 1, 1, 1, 1, 1, "S",  107.29,  2.9028,   "mm", "BD1",  "A33380"
14750    DATA 1, 2, 1, 1, 1, "S",  107.42,  2.9517,   "mm", "BD2",  "A22090"
14760    DATA 1, 3, 1, 1, 1, "S",  107.42,  2.4609,   "mm", "BD3",  "A22091"
14770    DATA 1, 4, 1, 1, 1, "S",  6.8529,  0.0879,  "MPa","APR1",    "5817"
14780    DATA 1, 5, 1, 1, 1, "S",  6.8586,  0.0049,  "MPa","APE1",    "4986"
14790    DATA 1, 6, 1, 1, 1, "S",  6.8792,  0.0562,  "MPa","APR2",    "5723"
14800    DATA 1, 7, 1, 1, 1, "S",  6.8636,  0.0708,  "MPa","APE2",    "5815"
14810    DATA 1, 8, 1, 1, 1, "S",  6.8643,  0.0806,  "MPa","APR3",    "5883"
14820    DATA 1, 9, 1, 1, 1, "S",  6.8531,  0.0562,  "MPa","APE3",    "5885"
14830    DATA 1,10, 1, 1, 1, "S",  13.709,  0.0757,  "MPa", "BP1",    "5887"
14840    DATA 1,11, 1, 1, 1, "S",  13.712,  0.0000,  "MPa", "BP2",    "5773"
14850    DATA 1,12, 1, 1, 1, "S",  13.734,  0.0806,  "MPa", "BP3",    "5892"
14860    DATA 1,13, 1, 1, 1, "S",  13.731,  0.0708,  "MPa", "BP4",    "5889"
14870    DATA 1,14, 1, 1, 1, "S",  13.717,  0.0000,  "MPa", "BP5",    "5891"
14880    DATA 1,15, 1, 1, 2, "S",     1.0,       0,  "  V","RAMP",   "     "
14890    DATA 1,16, 1, 1, 1, "S",  1000.0,       0,   "uE","BR1B",   "     "
14900 Card2:!
14910    DATA 2, 1 ,1, 1, 2, "S",  53.906,  1.4160,   "mm", "AD1",  "A22091"
14920    DATA 2, 2, 1, 1, 2, "S",  53.634,  1.4014,   "mm", "AD2",  "A33381"
14930    DATA 2, 3, 1, 1, 2, "S",  53.608,  1.6895,   "mm", "AD3",  "A33382"
14940    DATA 2, 4, 1, 1, 1, "S",  1000.0,       0,   "uE","BR1A",   "     "
14950    DATA 2, 5, 1, 1, 1, "S",  1000.0,       0,   "uE","FSG2",   "     "
14960    DATA 2, 6, 1, 1, 1, "S",  1000.0,       0,   "uE","FSG3",   "     "
14970    DATA 2, 7, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS7",   "     "
14980    DATA 2, 8, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS8",   "     "
14990    DATA 2, 9, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS9",   "     "
15000    DATA 2,10, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS1",   "     "
15010    DATA 2,11, 1, 1, 1, "S",  1000.0,       0,   "uE","BR2B",   "     "
15020    DATA 2,12, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS3",   "     "
15030    DATA 2,13, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS4",   "     "
15040    DATA 2,14, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS5",   "     "
15050    DATA 2,15, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS6",   "     "
15060    DATA 2,16, 1, 1, 1, "S",  1000.0,       0,   "uE","BR1C",   "     "
15070    !-----¦--¦--¦--¦--¦----¦--------¦--------¦-------¦------¦---------¦
15080    !Card ¦Ch¦SW¦HW¦Ex¦Mode¦  Gain  ¦ Offset ¦ Units ¦  Ch  ¦  Serial ¦
15090    ! no. ¦no¦gn¦gn¦gn¦    ¦ (Eng/V)¦  (V)   ¦ (/V)  ¦  Id  ¦  Number ¦
15100    !-----¦--¦--¦--¦--¦----¦--------¦--------¦-------¦------¦---------¦
15110 End_transducers:!
```

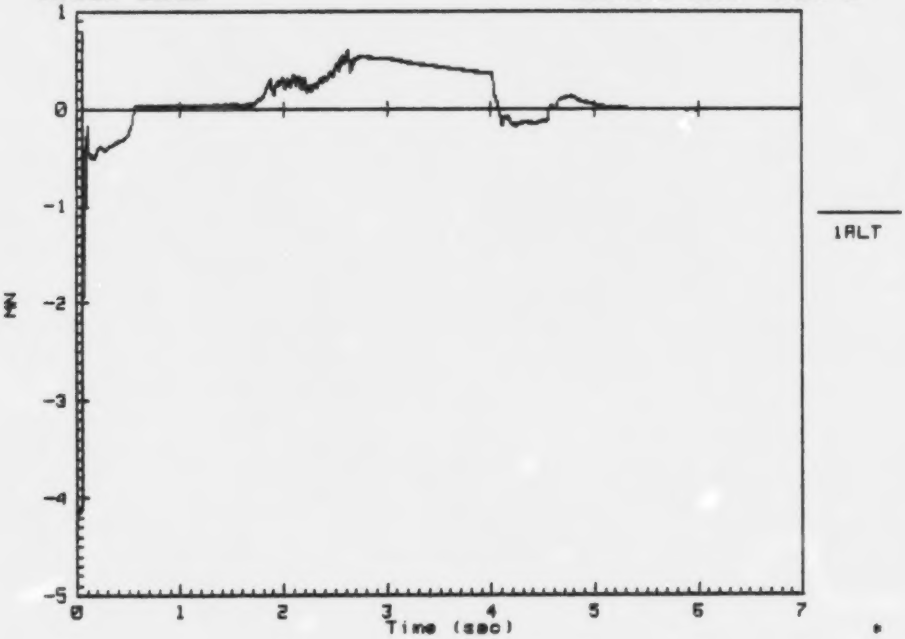
GEOTECHnical Resources Ltd. ANALYSIS DATE:11 May 1988

Command **Series PBT Test 6**



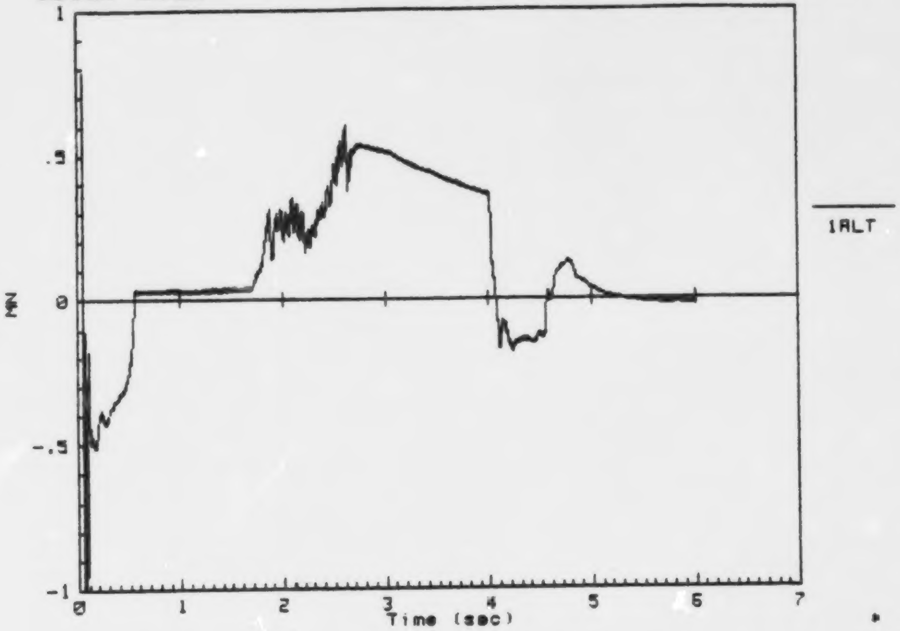
GEOTECHnical Resources Ltd. ANALYSIS DATE:11 May 1988

Total Load **Series PBT Test 6**



GEOTECHnical Resources Ltd. ANALYSIS DATE: 11 May 1988

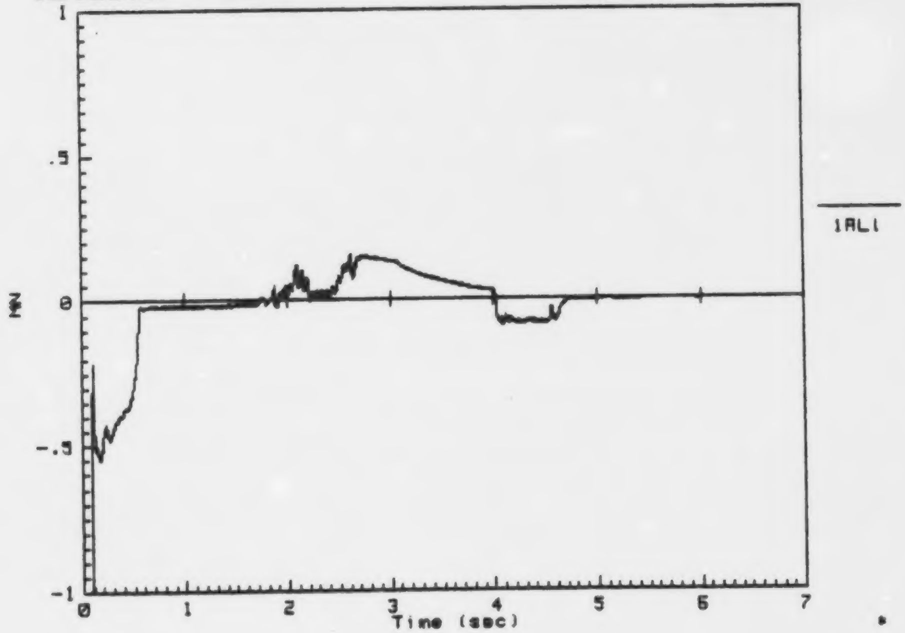
Total Load **Series PBT Test 6**



Peak load
≐ 0.37 MN
@ 2.[illegible] s

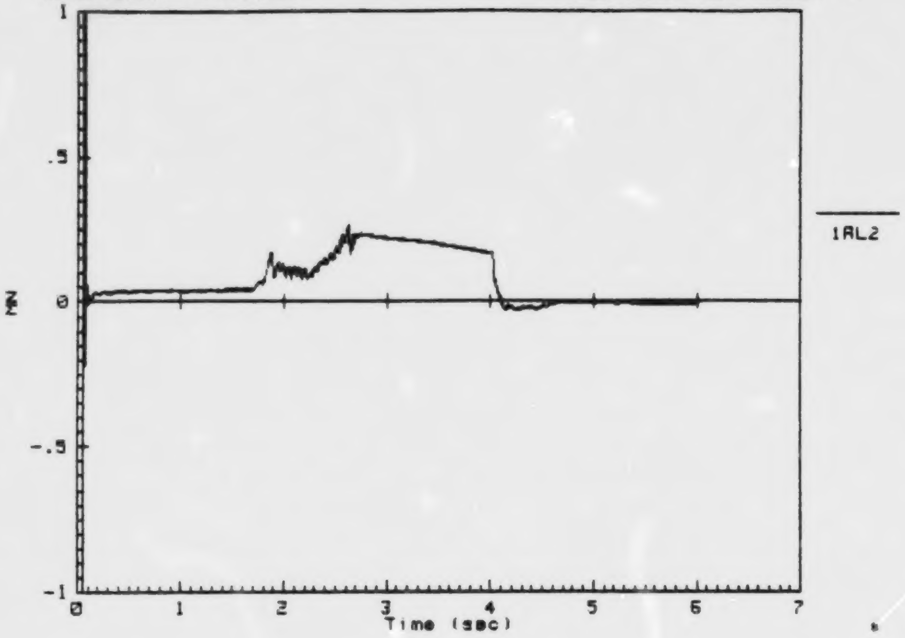
GEOTECHnical Resources Ltd. ANALYSIS DATE: 11 May 1988

Actuator 1 Load **Series PBT Test 6**



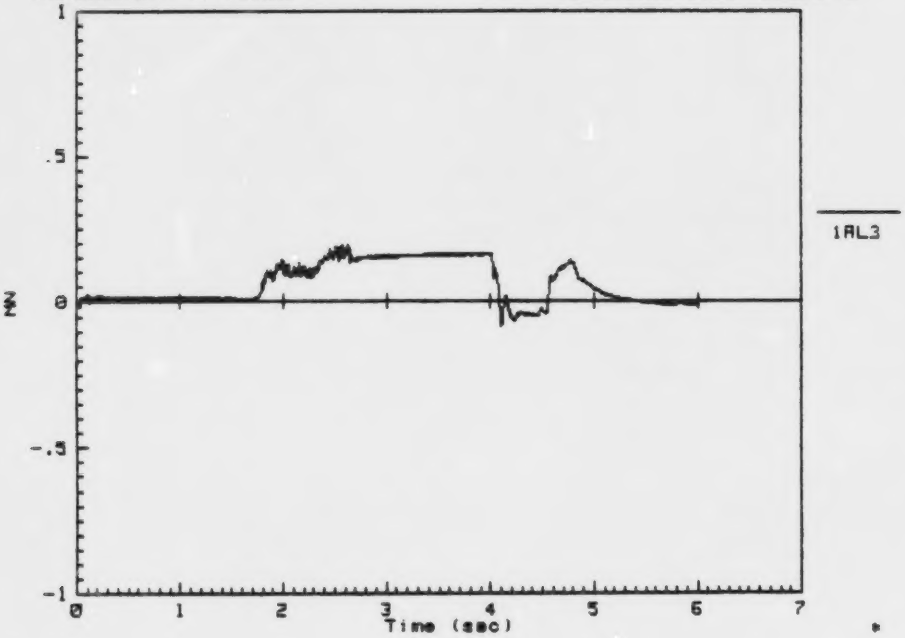
GEOTECHnical Resources Ltd. ANALYSIS DATE:11 May 1988

Actuator 2 Load **Series PBT Test 6**



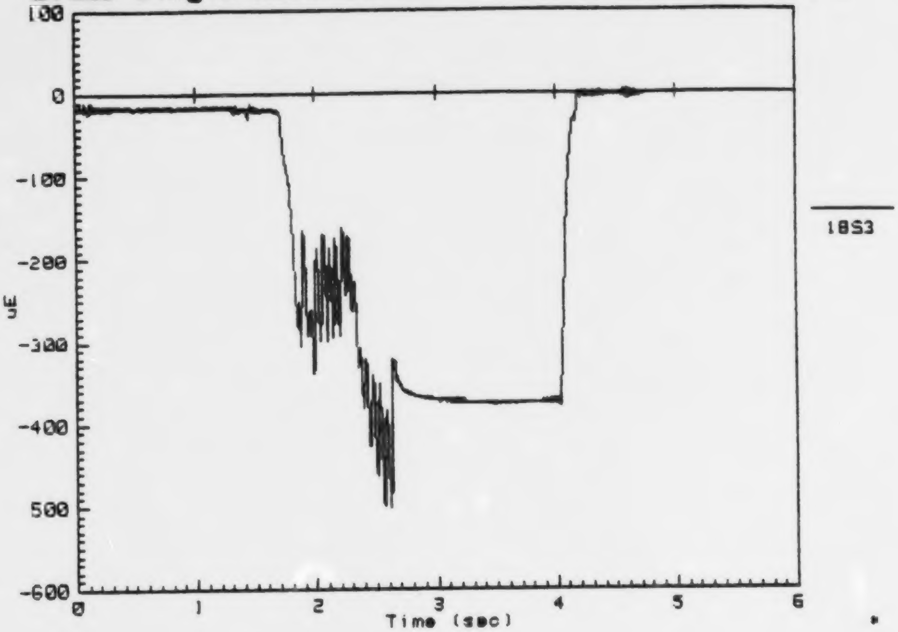
GEOTECHnical Resources Ltd. ANALYSIS DATE:11 May 1988

Actuator 3 Load **Series PBT Test 6**



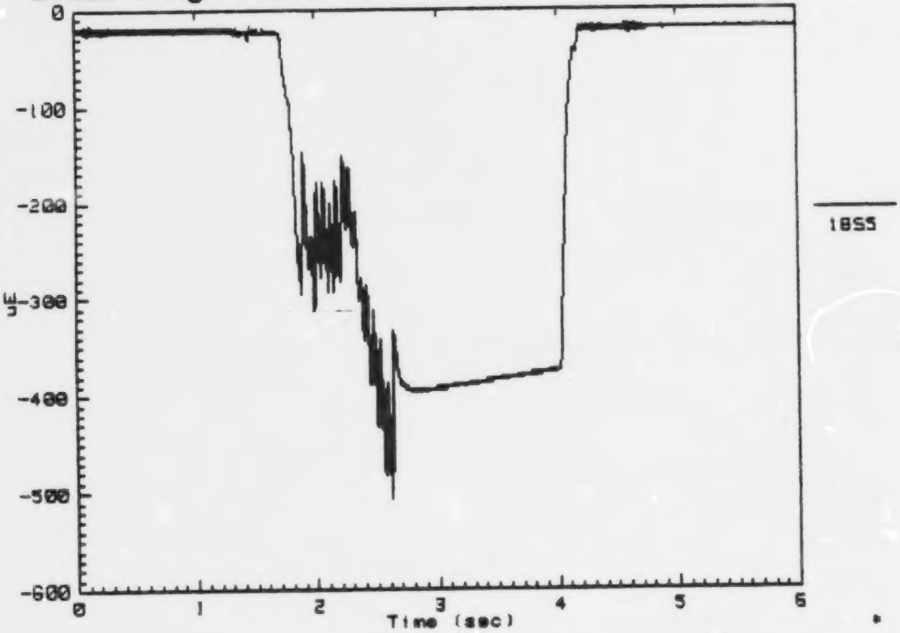
GEOTECHnical Resources Ltd.   ANALYSIS DATE:11 May 1988

Blade Single-Axis Strain   Series PBT Test 6



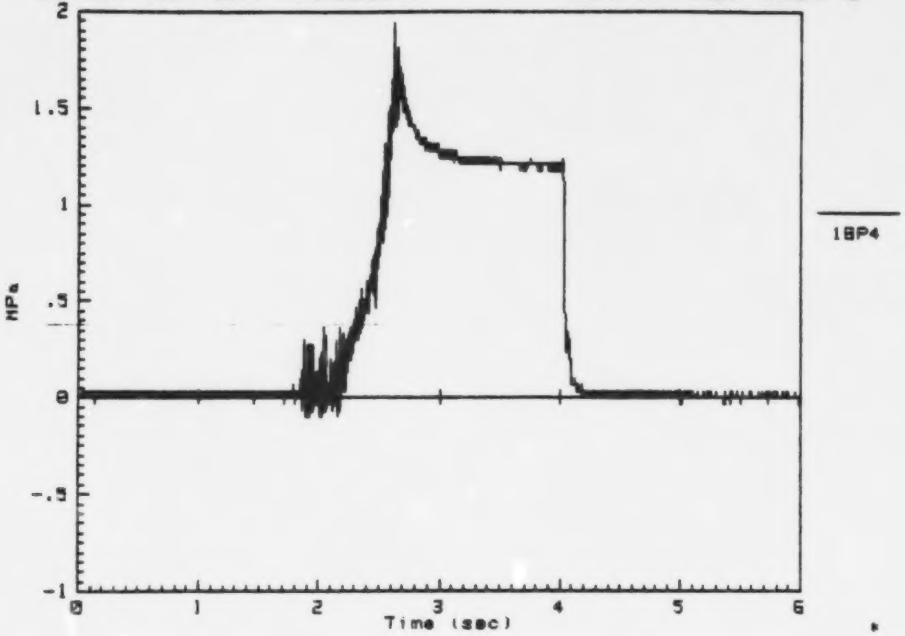
GEOTECHnical Resources Ltd.   ANALYSIS DATE:11 May 1988

Blade Single-Axis Strain   Series PBT Test 6



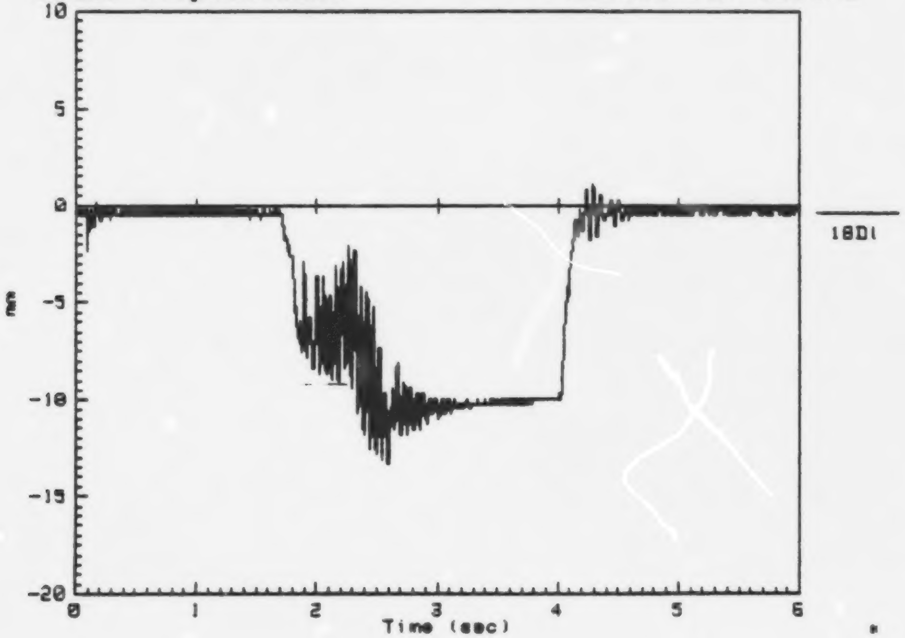
GEOTECHnical Resources Ltd.   ANALYSIS DATE: 11 May 1988

Blade Surface Pressure   **Series PBT Test 6**



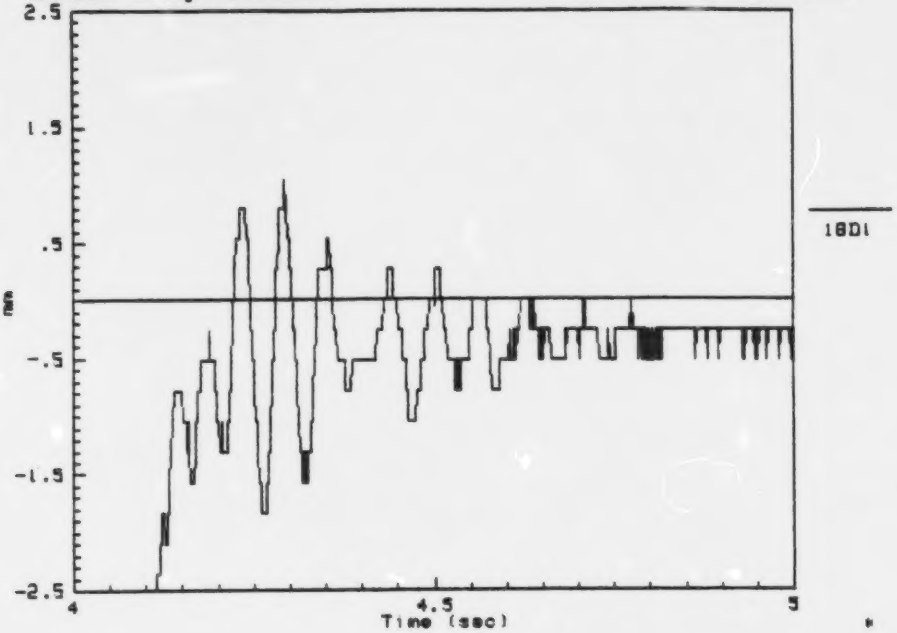
GEOTECHnical Resources Ltd.   ANALYSIS DATE: 11 May 1988

Blade Displacement   **Series PBT Test 6**



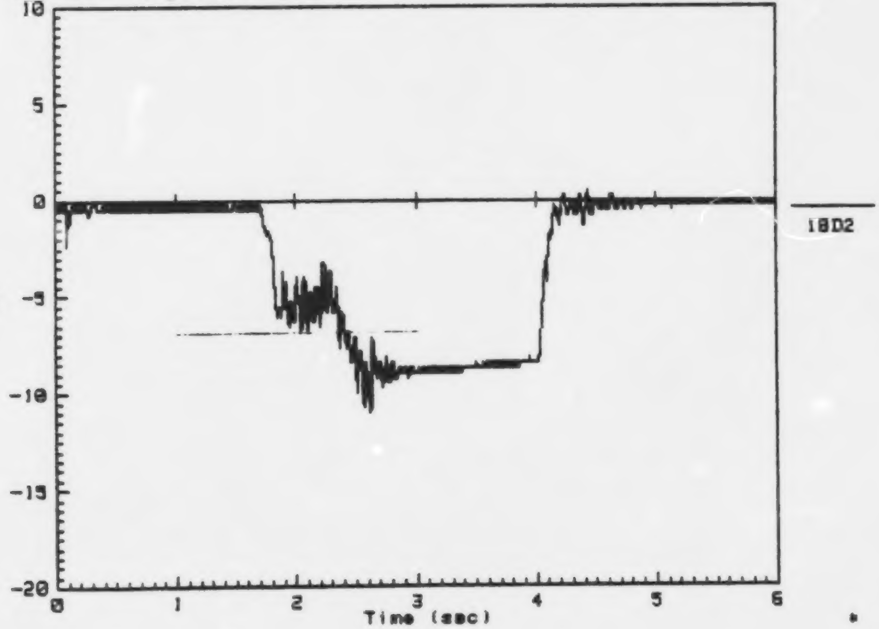
GEOTECHnical Resources Ltd. ANALYSIS DATE:11 May 1988

Blade Displacement **Series PBT Test 6**



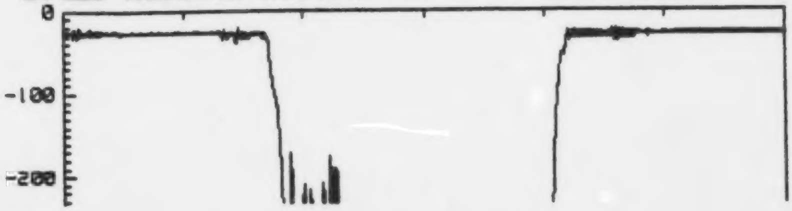
GEOTECHnical Resources Ltd. ANALYSIS DATE:11 May 1988

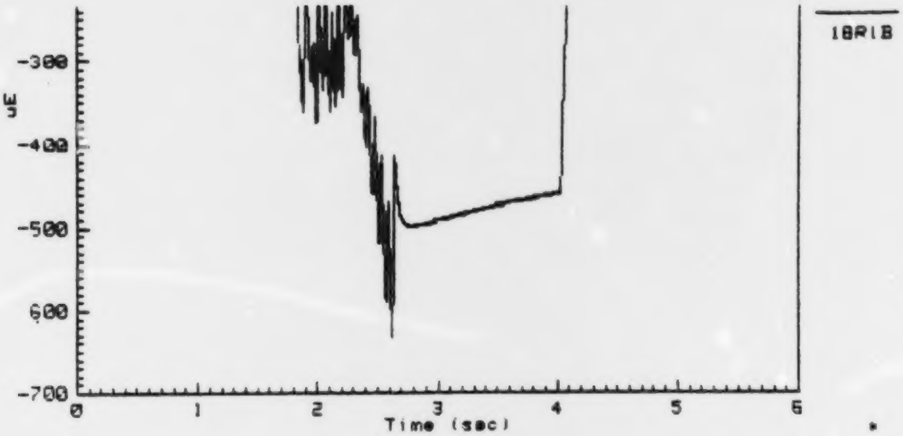
Blade Displacement **Series PBT Test 6**



GEOTECHnical Resources Ltd. ANALYSIS DATE:11 May 1988

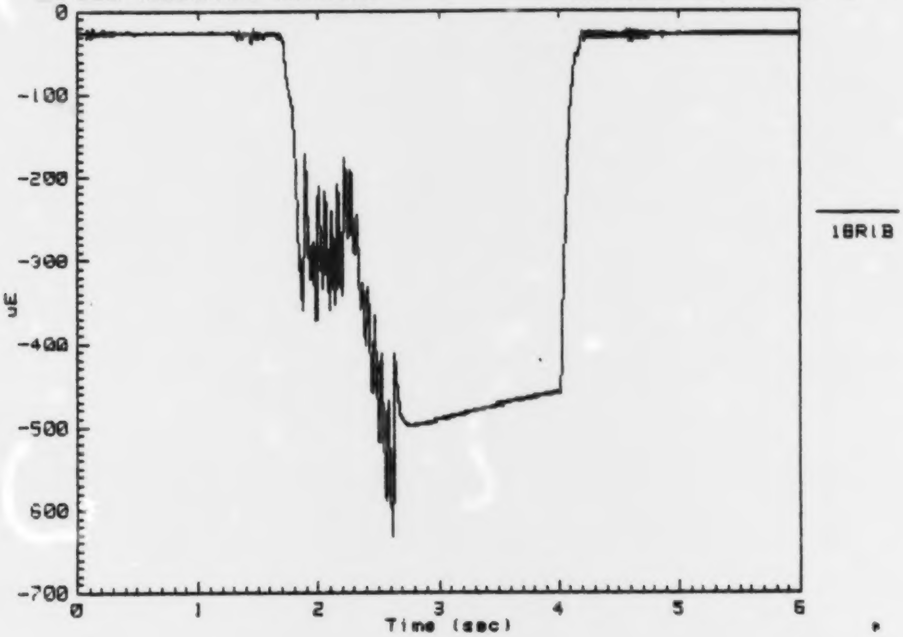
Blade Rosette Strain **Series PBT Test 6**





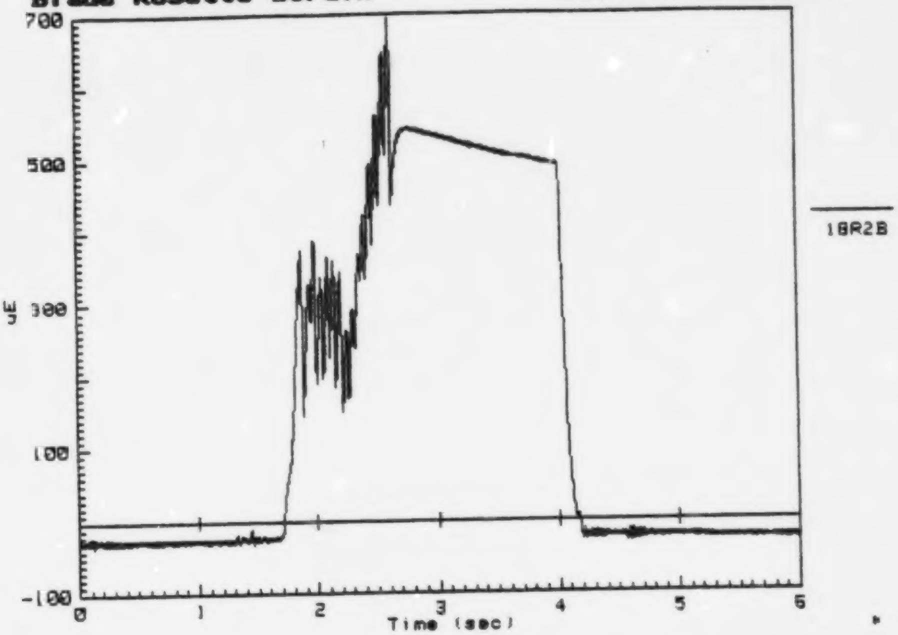
GEOTECHnical Resources Ltd. ANALYSIS DATE:11 May 1988

Blade Rosette Strain **Series PBT Test 6**



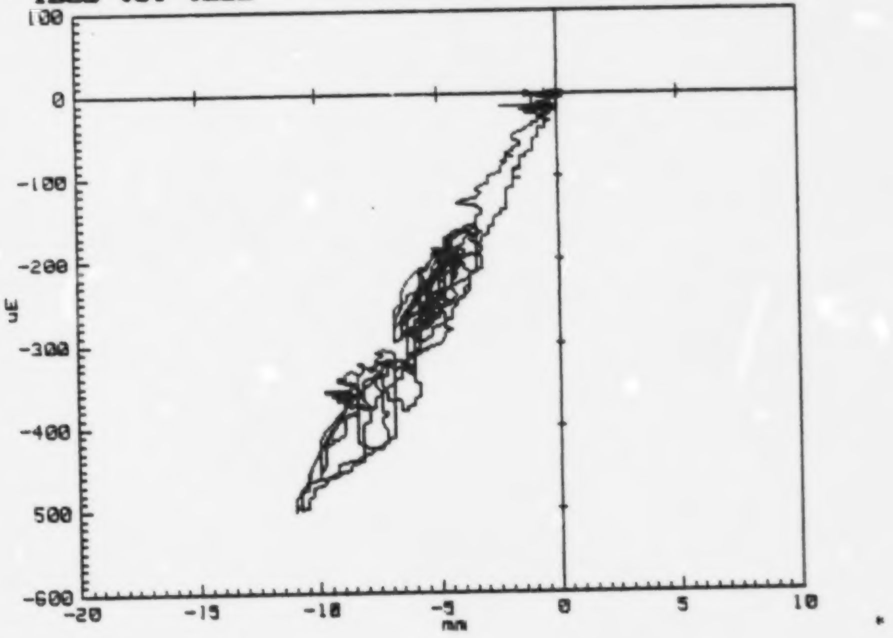
GEOTECHnical Resources Ltd. ANALYSIS DATE:11 May 1988

Blade Rosette Strain **Series PBT Test 6**



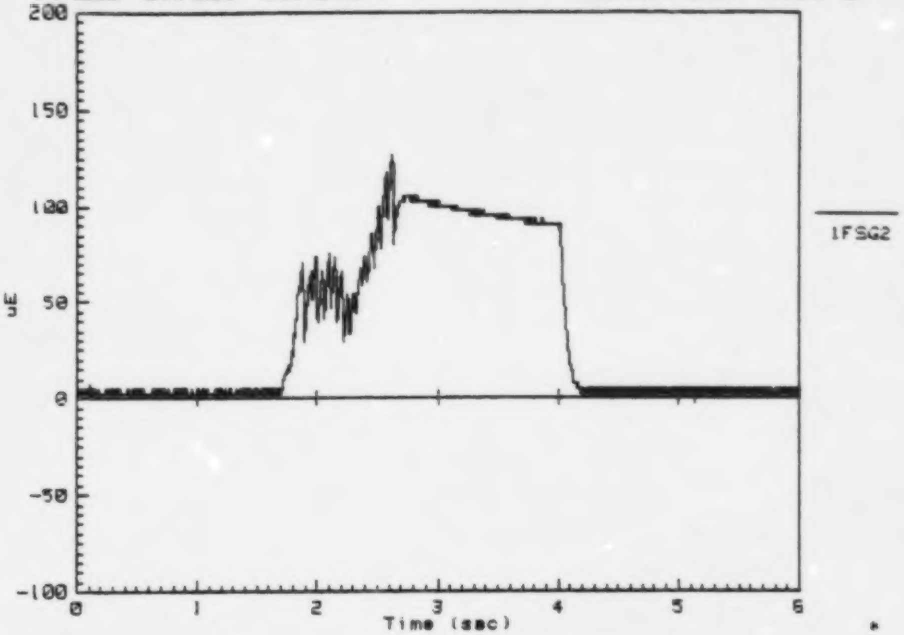
GEOTECHnical Resources Ltd. ANALYSIS DATE:11 May 1988

1BS3 vs. 1BD2 **Series PBT Test 6**



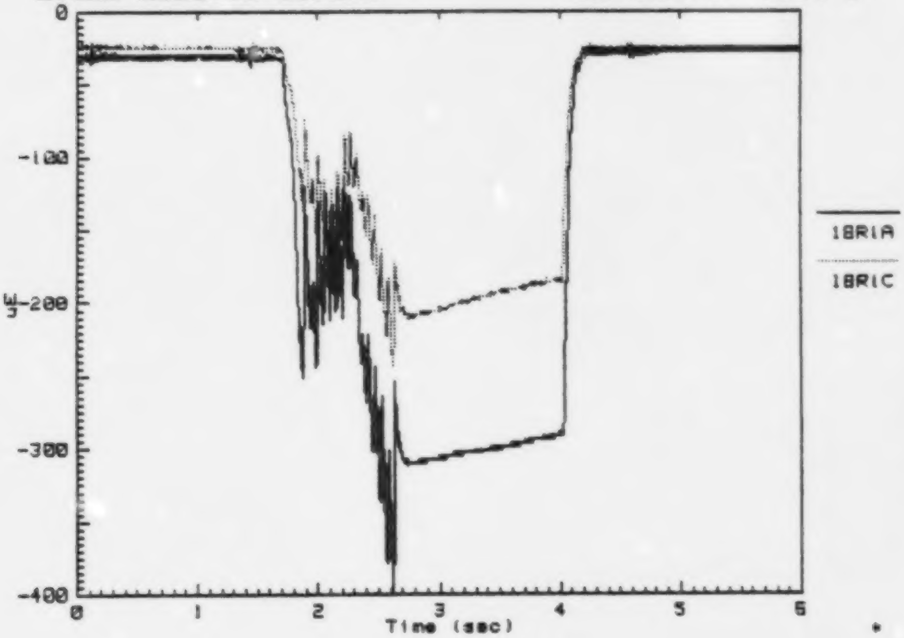
GEOTECHnical Resources Ltd. ANALYSIS DATE: 11 May 1988

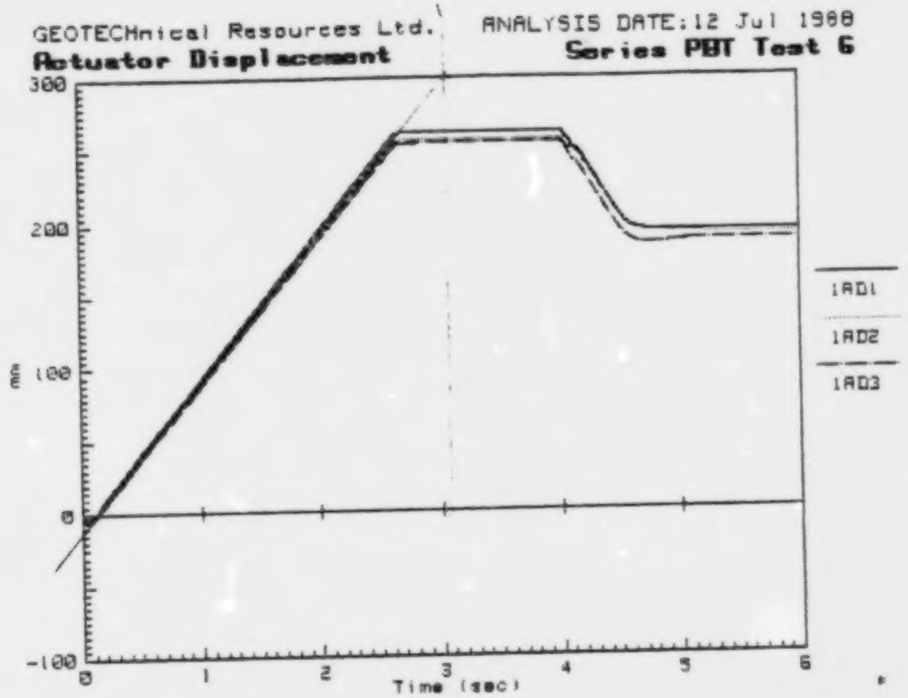
Frame Girder Strain **Series PBT Test 6**



GEOTECHnical Resources Ltd. ANALYSIS DATE: 11 May 1988

Blade Rosette Strain **Series PBT Test 6**



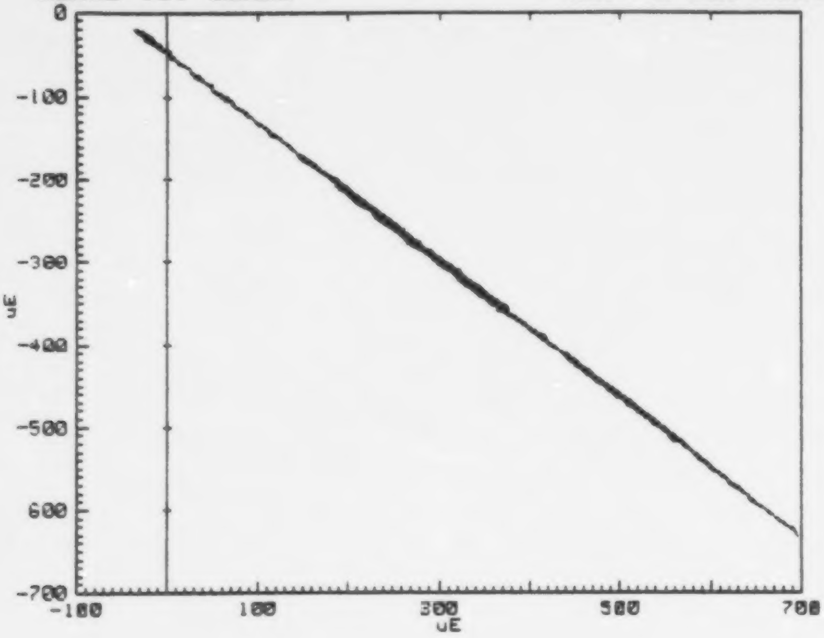


[illegible] mm
3.08 s

= 131.5 mm

GEOTECHnical Resources Ltd. ANALYSIS DATE:11 May 1988

1BR1B vs. 1BR2B **Series PBT Test 6**



```
                    GEOTECHnical resources ltd
                          PROP BUSTERS
                      PROJECT NUMBER: 9448


Date: 12 May 1988
Time: 11:48:05

Test series...... PBT
Test number...... 7

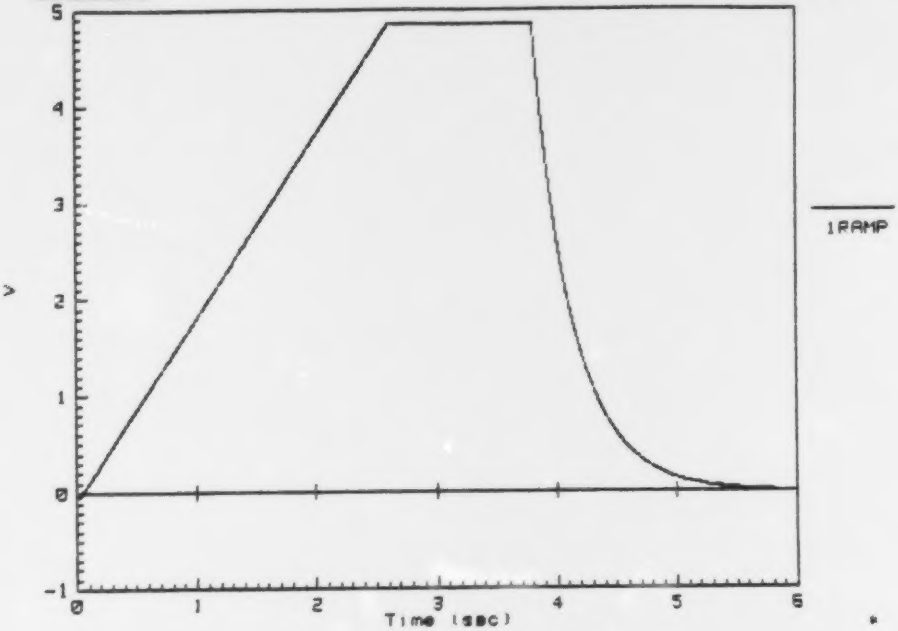
*** Window 1 ***
Test duration .................. 6 Second(s)
AD-200 sample period............ 16.1 Micro-second(s)
Sample rate, aggregate ......... 62111 Hz.
Sample rate per channel ........ 3881 Hz.
Number of samples per channel .. 23292 words.
Total number of samples ........ 745344 words.
Trigger source ................. INTERNAL
Number of cards ................ 2
Number of channels per card .... 16
Total number of channels ....... 32
```

Transducer table for test #PBT07_HDR

```
14680 Card1:!
14690   !-----!--!--!--!--!----!--------!--------!-------!------!---------!
14700   !Card !Ch!SW!HW!Ex!Mode!  Gain  ! Offset ! Units !  Ch  !  Serial !
14710   ! no. !no!gn!gn!gn!    ! (eng/V)!  (V)   ! (/V)  !  Id  !  Number !
14720   !-----!--!--!--!--!----!--------!--------!-------!------!---------!
14730   DATA 1, 1, 1, 1, 1, "S",  107.29,  2.9028,   "mm", "BD1",  "A33380"
14740   DATA 1, 2, 1, 1, 1, "S",  107.42,  2.9517,   "mm", "BD2",  "A22090"
14750   DATA 1, 3, 1, 1, 1, "S",  107.42,  2.4609,   "mm", "BD3",  "A22091"
14760   DATA 1, 4, 1, 1, 1, "S",  6.8529,  0.0879,  "MPa","APR1",    "5817"
14770   DATA 1, 5, 1, 1, 1, "S",  6.8586,  0.0049,  "MPa","APE1",    "4986"
14780   DATA 1, 6, 1, 1, 1, "S",  6.8792,  0.0562,  "MPa","APR2",    "5723"
14790   DATA 1, 7, 1, 1, 1, "S",  6.8636,  0.0708,  "MPa","APE2",    "5815"
14800   DATA 1, 8, 1, 1, 1, "S",  6.8643,  0.0806,  "MPa","APR3",    "5883"
14810   DATA 1, 9, 1, 1, 1, "S",  6.8531,  0.0562,  "MPa","APE3",    "5885"
14820   DATA 1,10, 1, 1, 1, "S",  13.709,  0.0757,  "MPa", "BP1",    "5887"
14830   DATA 1,11, 1, 1, 1, "S",  13.712,  0.1025,  "MPa", "BP2",    "5773"
14840   DATA 1,12, 1, 1, 1, "S",  13.734,  0.0806,  "MPa", "BP3",    "5892"
14850   DATA 1,13, 1, 1, 1, "S",  13.731,  0.0708,  "MPa", "BP4",    "5889"
14860   DATA 1,14, 1, 1, 1, "S",  13.717,  0.0000,  "MPa", "BP5",    "5891"
14870   DATA 1,15, 1, 1, 2, "S",     1.0,       0,  "  V","RAMP",  "      "
14880   DATA 1,16, 1, 1, 1, "S",  1000.0,       0,   "uE","BR1B",  "      "
14890 Card2:!
14900   DATA 2, 1 ,1, 1, 2, "S",  53.906,  1.4160,   "mm", "AD1",  "A22091"
14910   DATA 2, 2, 1, 1, 2, "S",  53.634,  1.4014,   "mm", "AD2",  "A33381"
14920   DATA 2, 3, 1, 1, 2, "S",  53.608,  1.6895,   "mm", "AD3",  "A33382"
14930   DATA 2, 4, 1, 1, 1, "S",  1000.0,       0,   "uE","BR1A",  "      "
14940   DATA 2, 5, 1, 1, 1, "S",  1000.0,       0,   "uE","FSG2",  "      "
14950   DATA 2, 6, 1, 1, 1, "S",  1000.0,       0,   "uE","FSG3",  "      "
14960   DATA 2, 7, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS7",  "      "
14970   DATA 2, 8, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS8",  "      "
14980   DATA 2, 9, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS9",  "      "
14990   DATA 2,10, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS1",  "      "
15000   DATA 2,11, 1, 1, 1, "S",  1000.0,       0,   "uE","BR2B",  "      "
15010   DATA 2,12, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS3",  "      "
15020   DATA 2,13, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS4",  "      "
15030   DATA 2,14, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS5",  "      "
15040   DATA 2,15, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS6",  "      "
15050   DATA 2,16, 1, 1, 1, "S",  1000.0,       0,   "uE","BR1C",  "      "
15060   !-----!--!--!--!--!----!--------!--------!-------!------!---------!
15070   !Card !Ch!SW!HW!Ex!Mode!  Gain  ! Offset ! Units !  Ch  !  Serial !
15080   ! no. !no!gn!gn!gn!    ! (Eng/V)!  (V)   ! (/V)  !  Id  !  Number !
15090   !-----!--!--!--!--!----!--------!--------!-------!------!---------!
15100 End_transducers:!
```

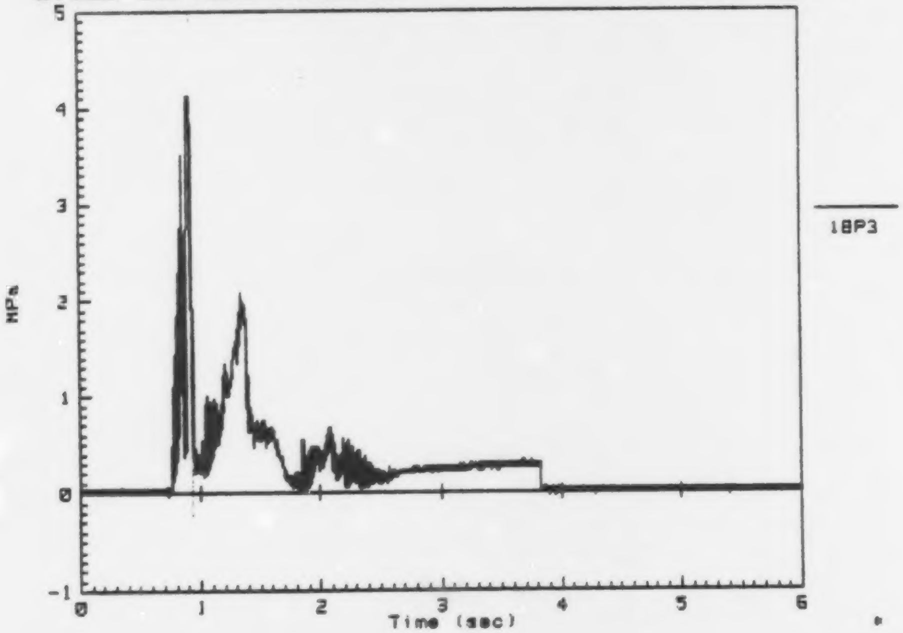
GEOTECHnical Resources Ltd.　ANALYSIS DATE:12 May 1988

Command　**Series PBT Test 7**



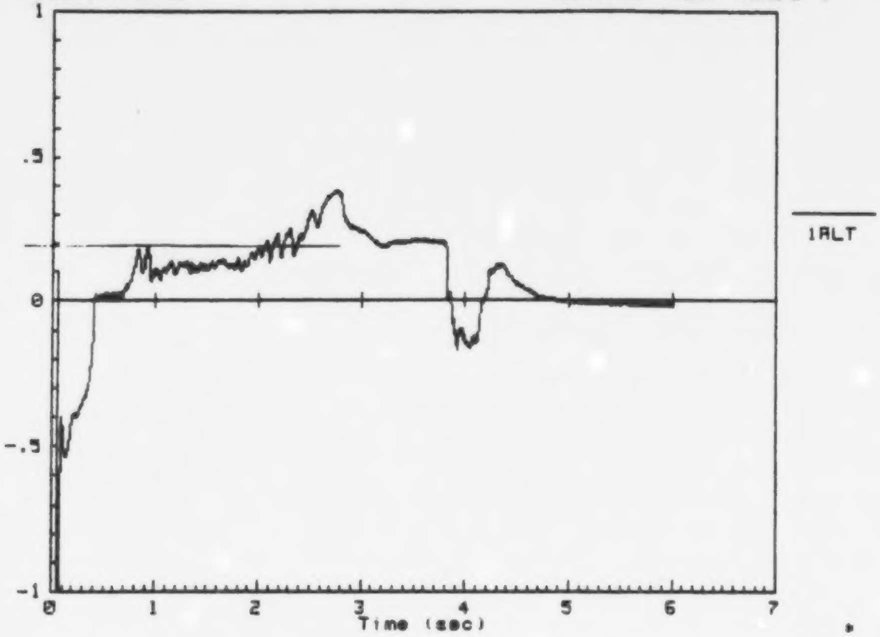
GEOTECHnical Resources Ltd.　ANALYSIS DATE:12 May 1988

Blade Surface Pressure　**Series PBT Test 7**



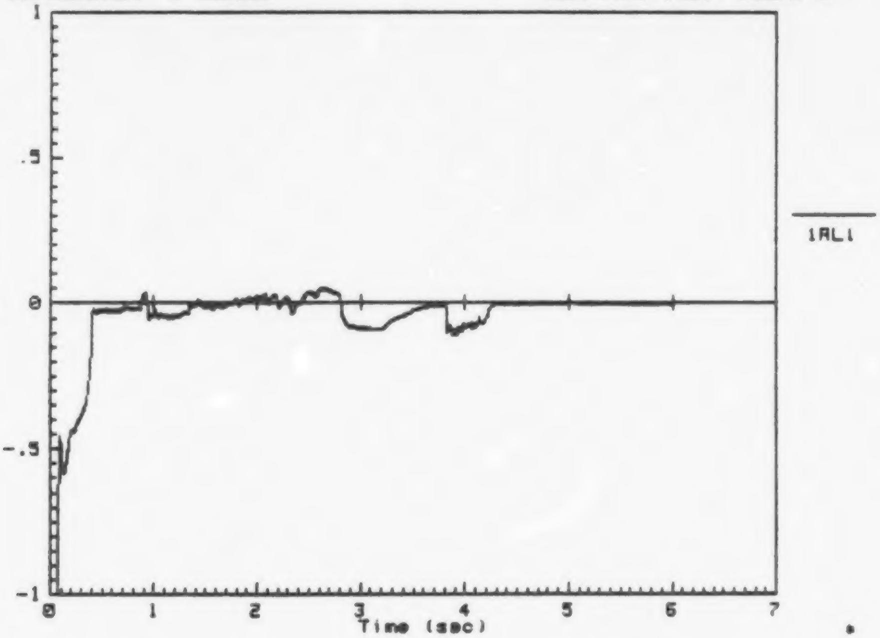
GEOTECHnical Resources Ltd.   ANALYSIS DATE:12 May 1988

Total Load   **Series PBT Test 7**



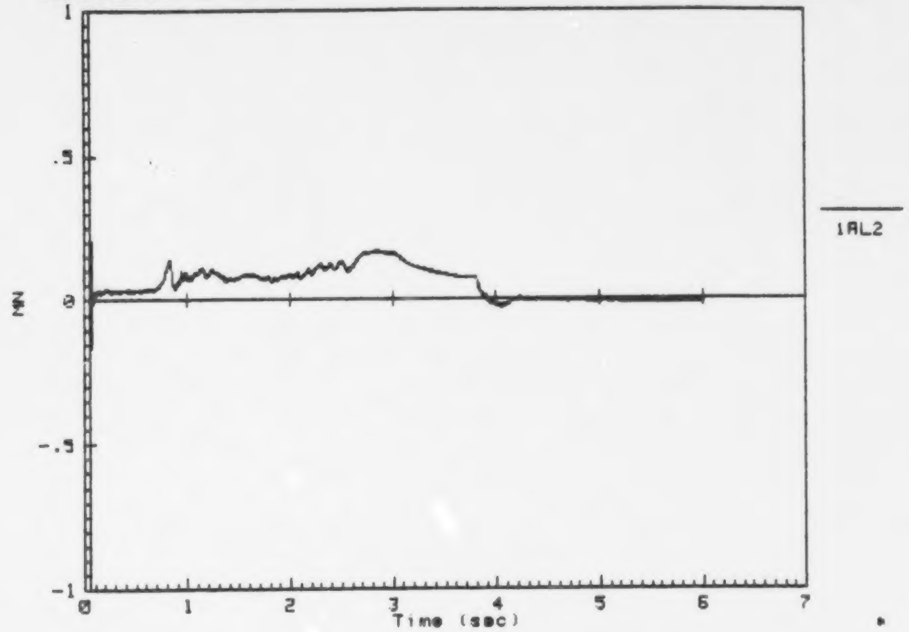
GEOTECHnical Resources Ltd.   ANALYSIS DATE:12 May 1988

Actuator 1 Load   **Series PBT Test 7**



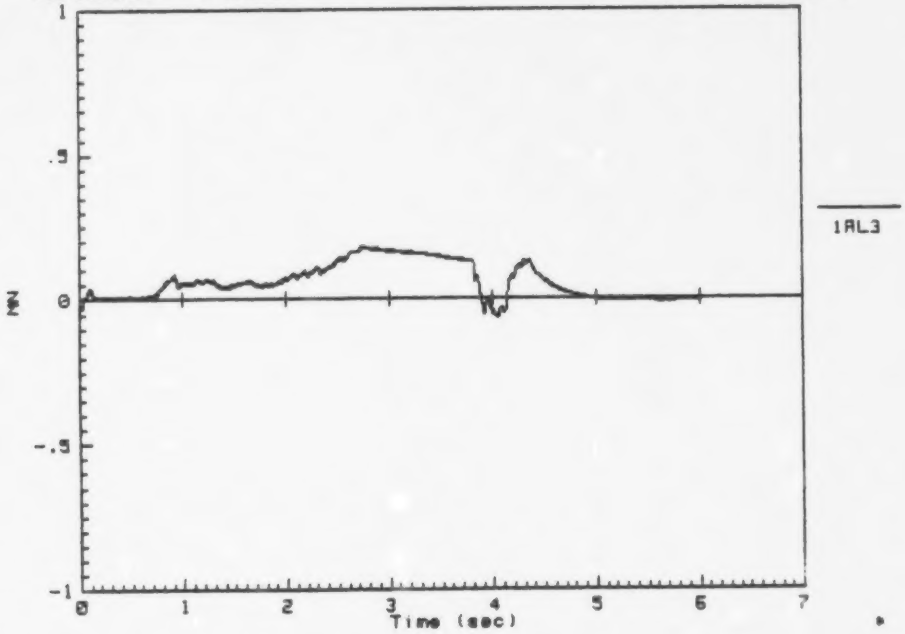
GEOTECHnical Resources Ltd.   ANALYSIS DATE: 12 May 1988

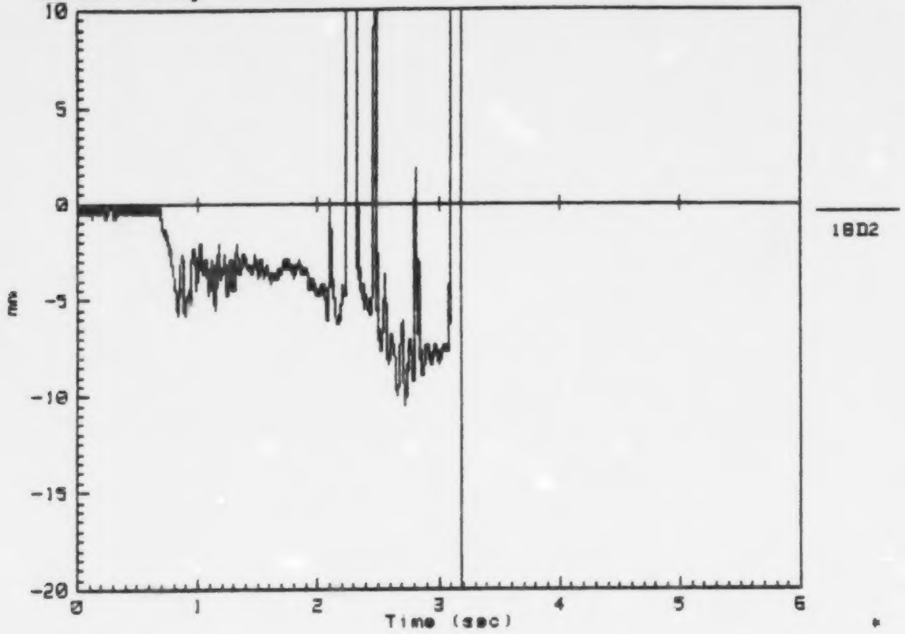
Actuator 2 Load   **Series PBT Test 7**



GEOTECHnical Resources Ltd.   ANALYSIS DATE: 12 May 1988

Actuator 3 Load   **Series PBT Test 7**



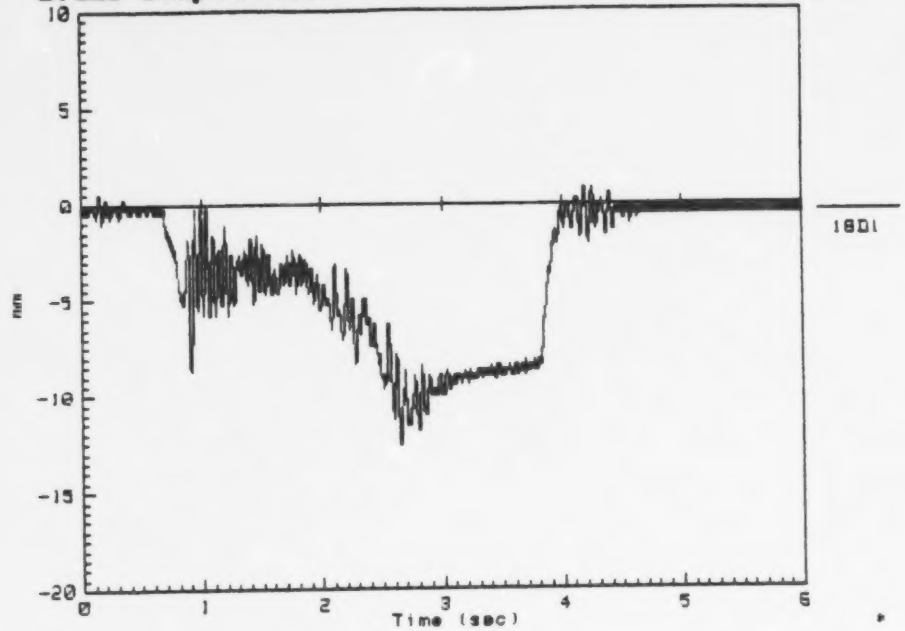


GEOTECHnical Resources Ltd. ANALYSIS DATE:12 May 1988

Blade Displacement **Series PBT Test 7**

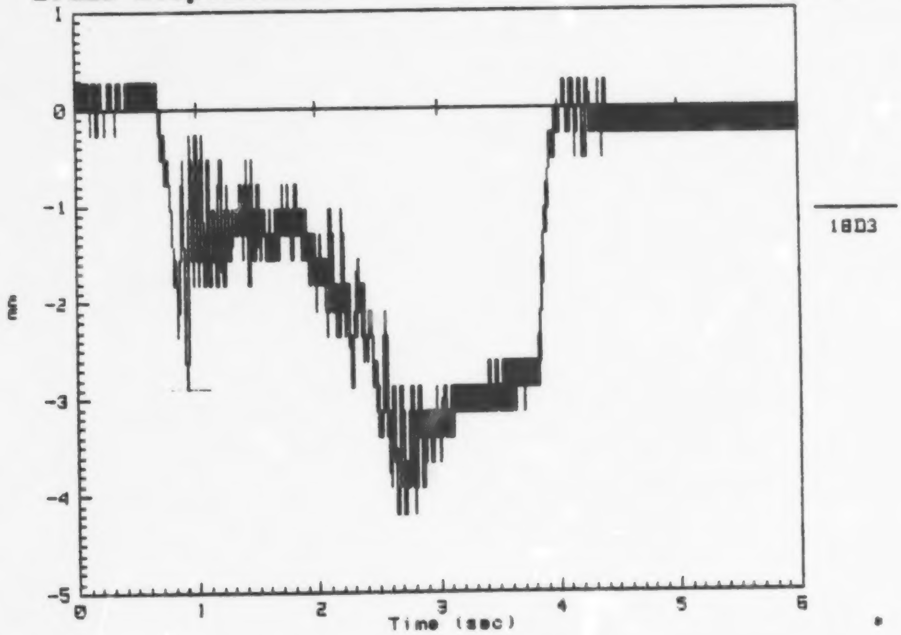
GEOTECHnical Resources Ltd. ANALYSIS DATE:12 May 1988

Blade Displacement **Series PBT Test 7**



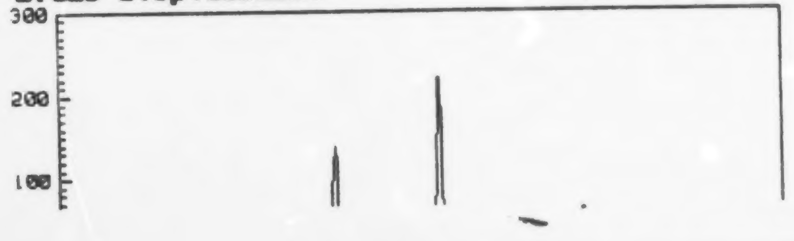
GEOTECHnical Resources Ltd. ANALYSIS DATE:12 May 1988

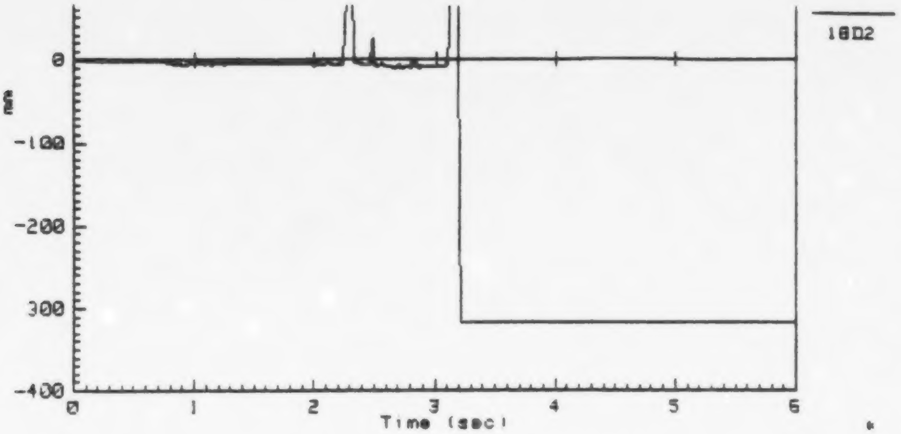
Blade Displacement **Series PBT Test 7**



GEOTECHnical Resources Ltd. ANALYSIS DATE:12 May 1988

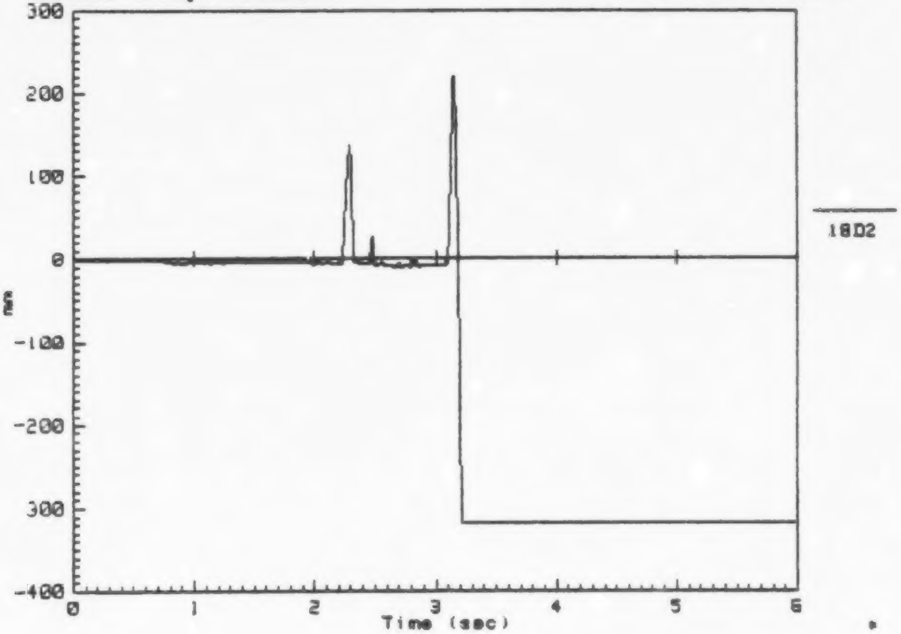
Blade Displacement **Series PBT Test 7**





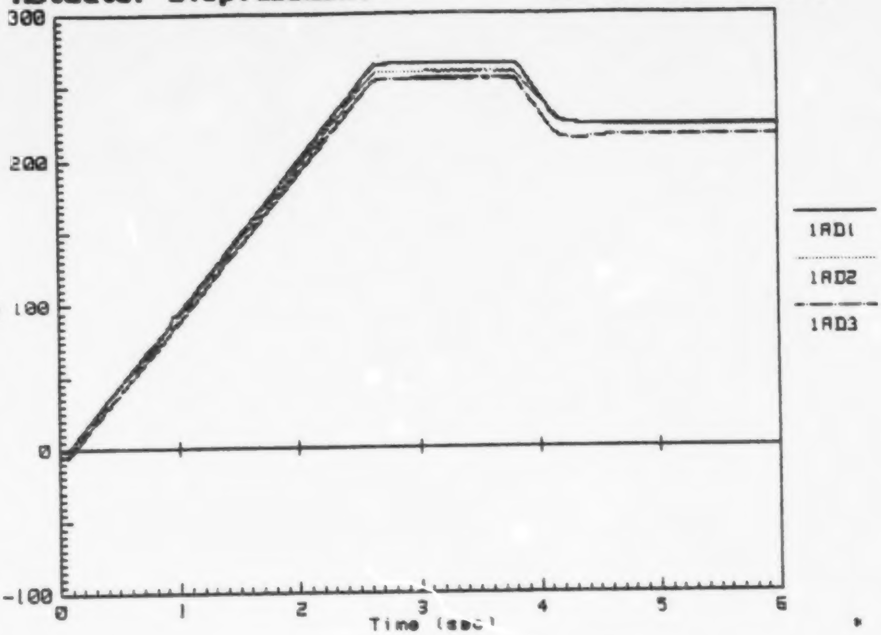
GEOTECHnical Resources Ltd.   ANALYSIS DATE:12 May 1988

Blade Displacement   **Series PBT Test 7**



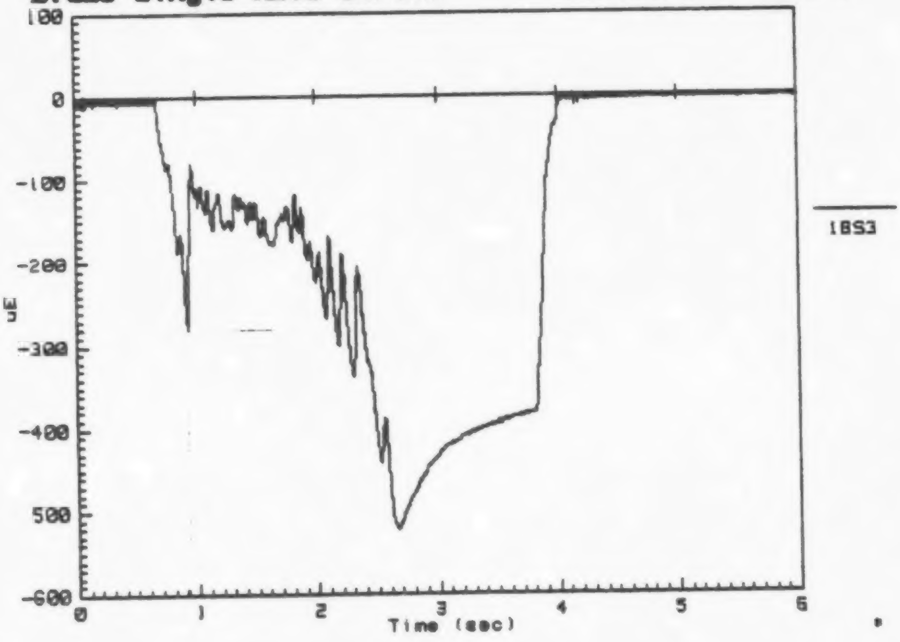
GEOTECHnical Resources Ltd. ANALYSIS DATE: 12 May 1988

Actuator Displacement **Series PBT Test 7**



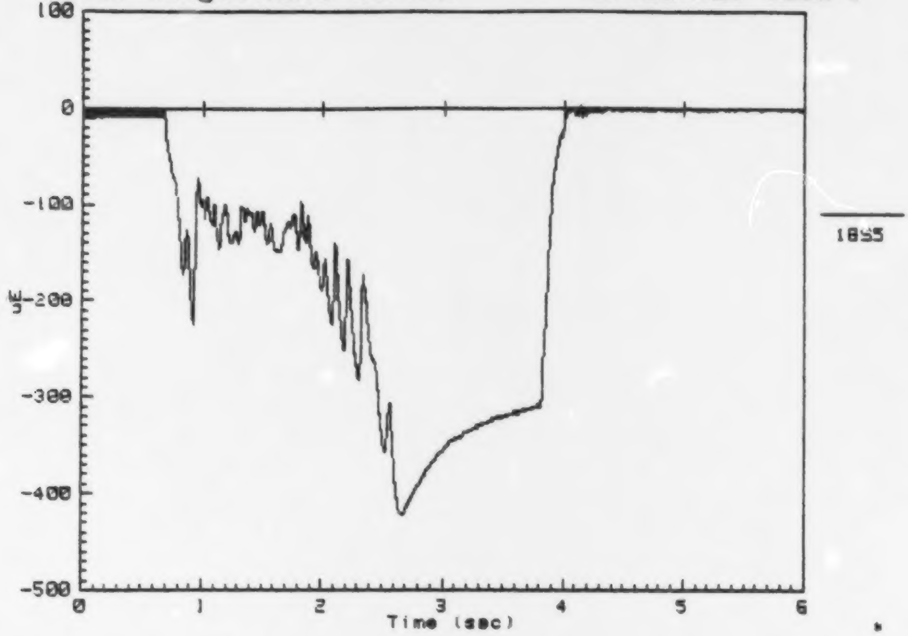
GEOTECHnical Resources Ltd. ANALYSIS DATE: 12 May 1988

Blade Single-Axis Strain **Series PBT Test 7**



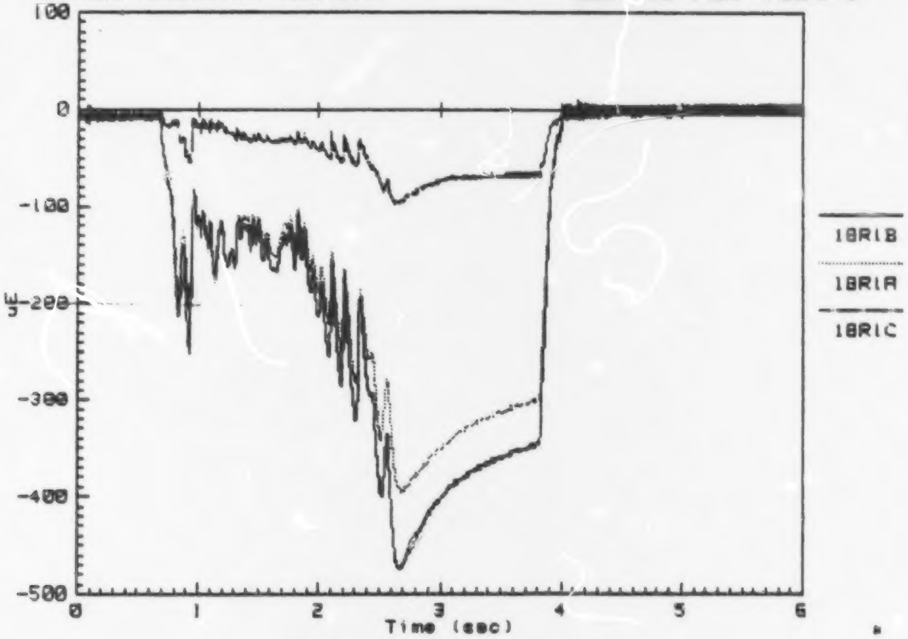
GEOTECHnical Resources Ltd.   ANALYSIS DATE: 12 May 1988

Blade Single-Axis Strain   **Series PBT Test 7**



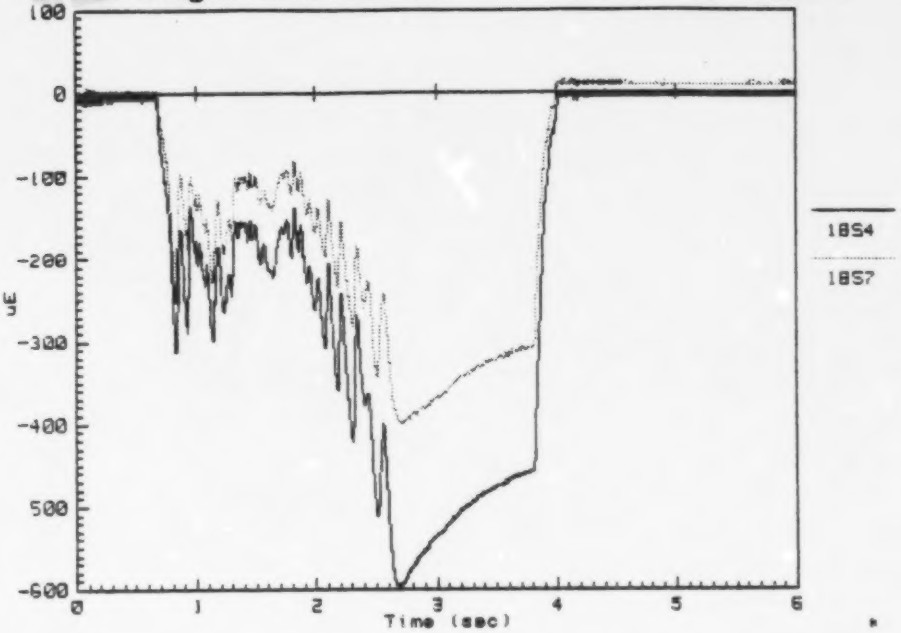
GEOTECHnical Resources Ltd.   ANALYSIS DATE: 12 May 1988

Blade Rosette Strain   **Series PBT Test 7**



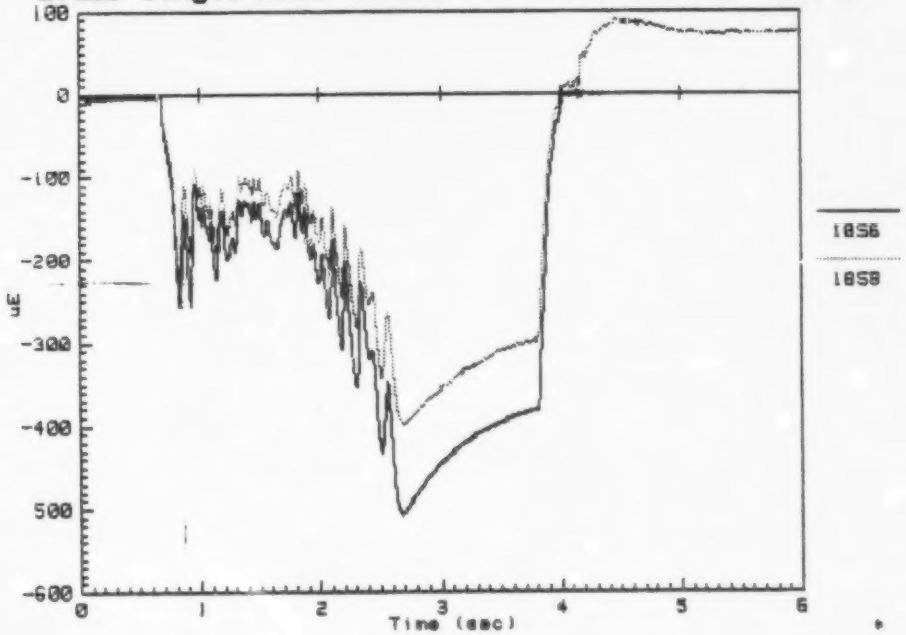
GEOTECHnical Resources Ltd. ANALYSIS DATE: 12 May 1988

Blade Single-Axis Strain **Series PBT Test 7**



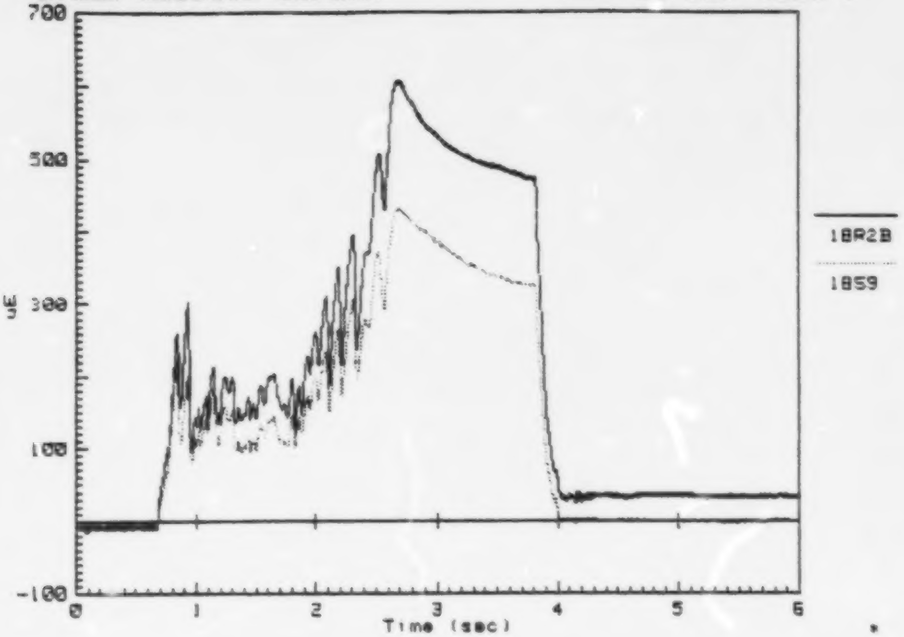
GEOTECHnical Resources Ltd. ANALYSIS DATE: 12 May 1988

Blade Single-Axis Strain **Series PBT Test 7**



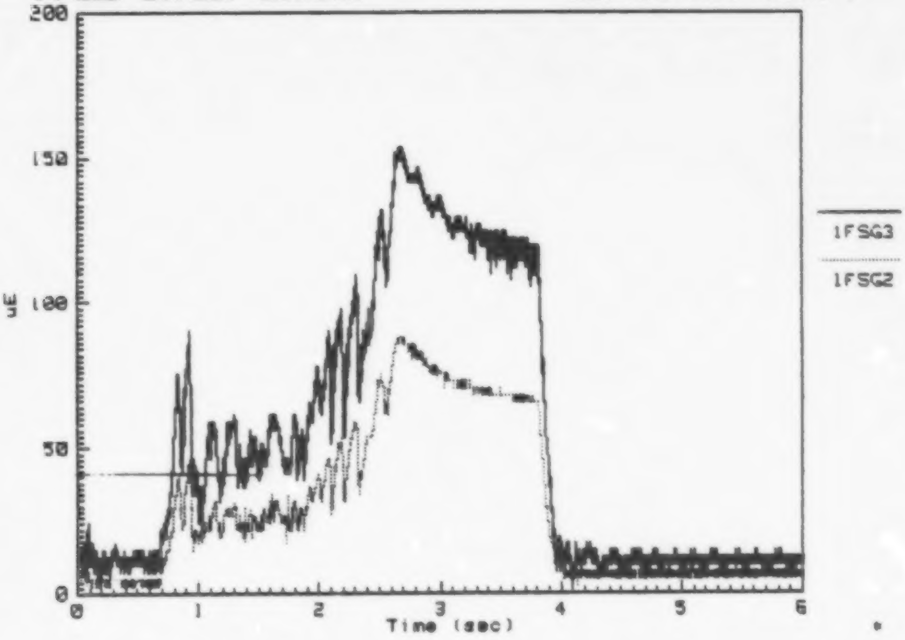
GEOTECHnical Resources Ltd.   ANALYSIS DATE:12 May 1988

Blade Rosette Strain   **Series PBT Test 7**



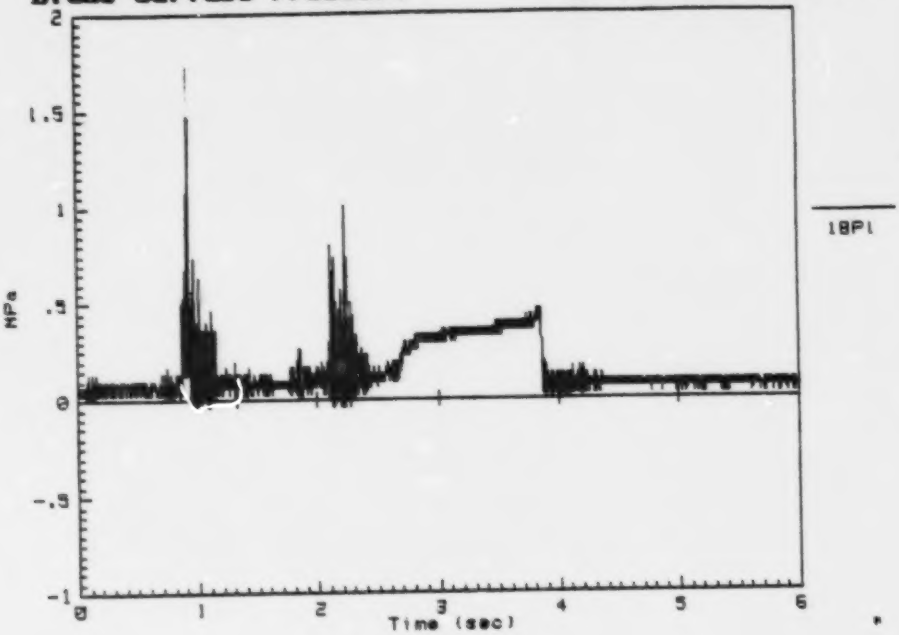
GEOTECHnical Resources Ltd.   ANALYSIS DATE:12 May 1988

Frame Girder Strain   **Series PBT Test 7**



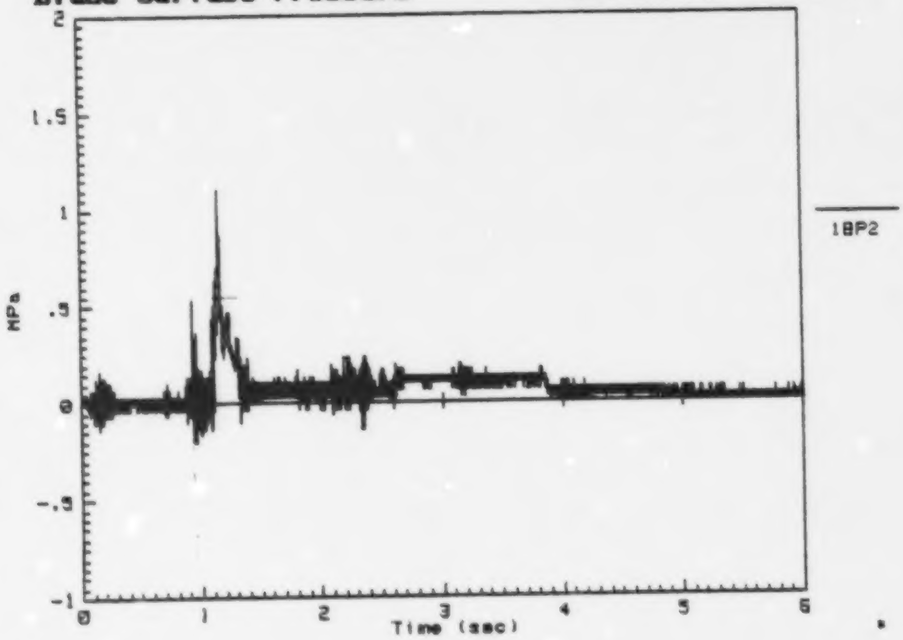
GEOTECHnical Resources Ltd.   ANALYSIS DATE: 12 May 1988

Blade Surface Pressure   **Series PBT Test 7**



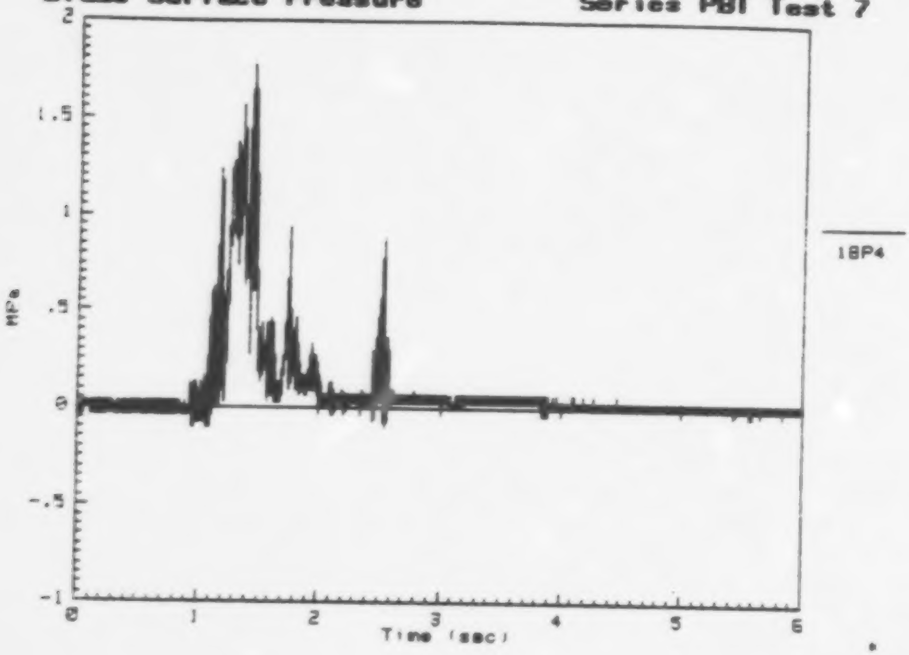
GEOTECHnical Resources Ltd.   ANALYSIS DATE: 12 May 1988

Blade Surface Pressure   **Series PBT Test 7**



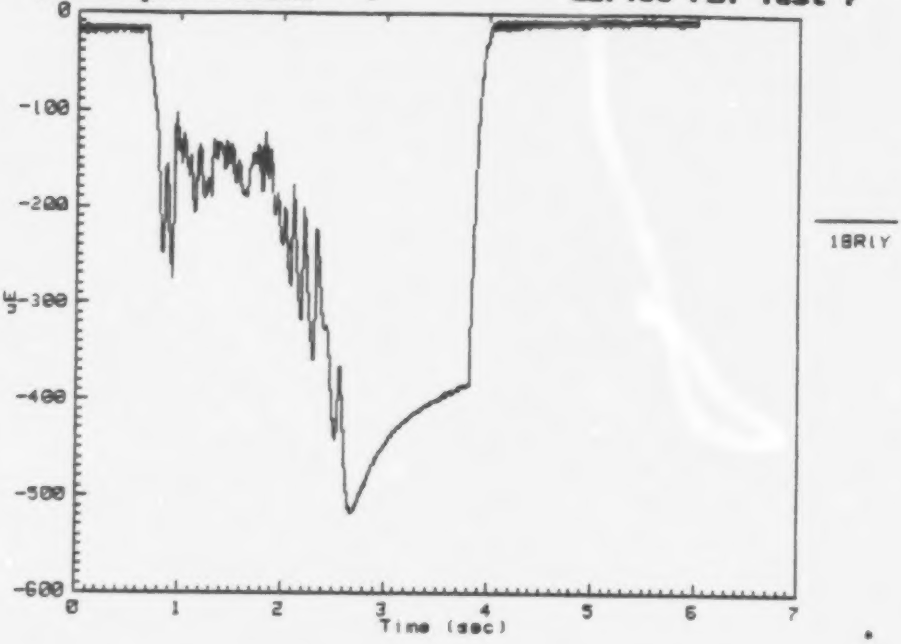
GEOTECHnical Resources Ltd. ANALYSIS DATE: 12 May 1988

Blade Surface Pressure **Series PBT Test 7**



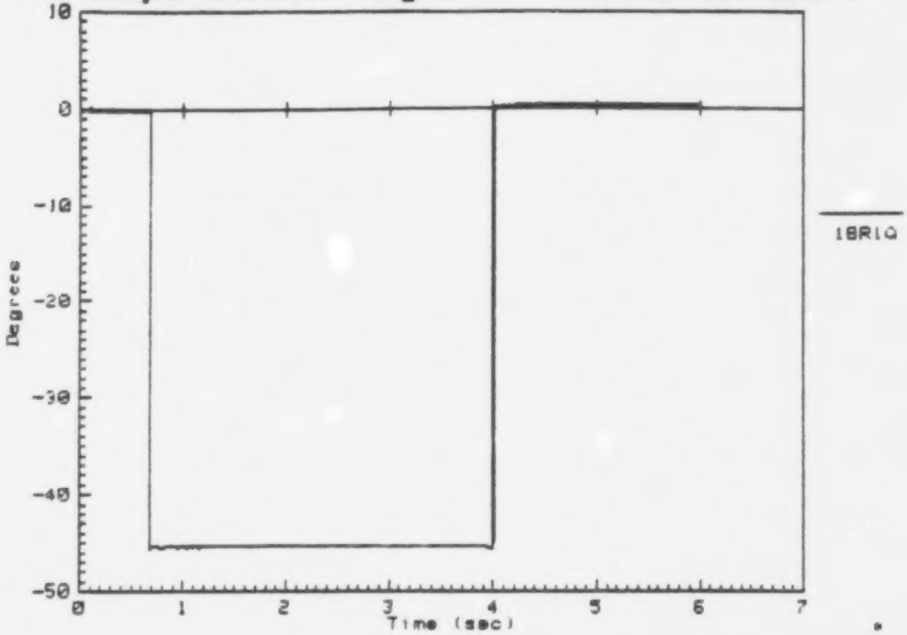
GEOTECHnical Resources Ltd. ANALYSIS DATE:13 May 1988

Principal Strain - Y **Series PBT Test 7**



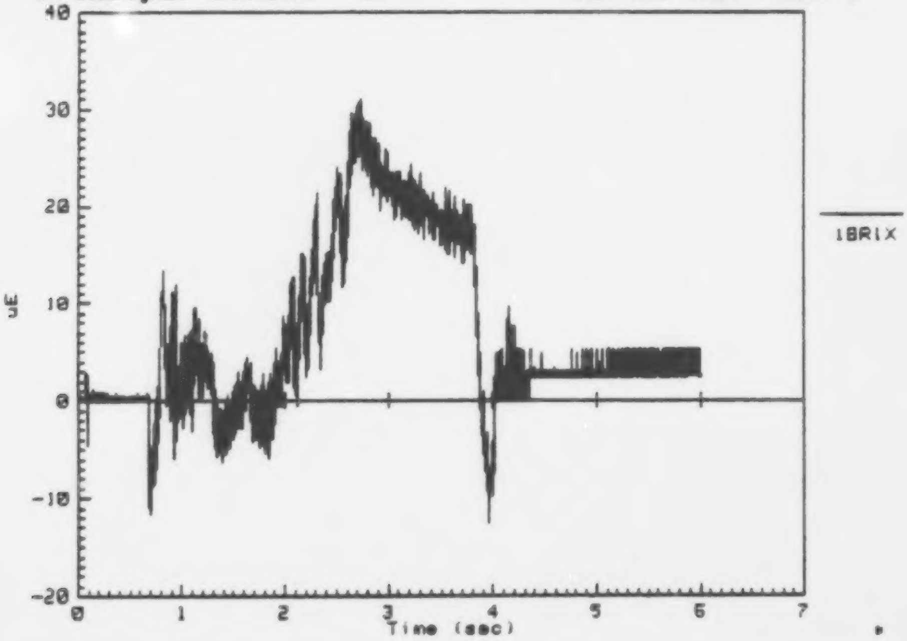
GEOTECHnical Resources Ltd. ANALYSIS DATE: 13 May 1988

Principal strain - Angle **Series PBT Test 7**



GEOTECHnical Resources Ltd. ANALYSIS DATE: 13 May 1988

Principal Strain - X **Series PBT Test 7**



K

```
                    GEOTECHnical resources ltd
                          PROP BUSTERS
                     PROJECT NUMBER: 9448


Date: 16 May 1988
Time: 11:18:35

Test series...... PBT
Test number...... 8

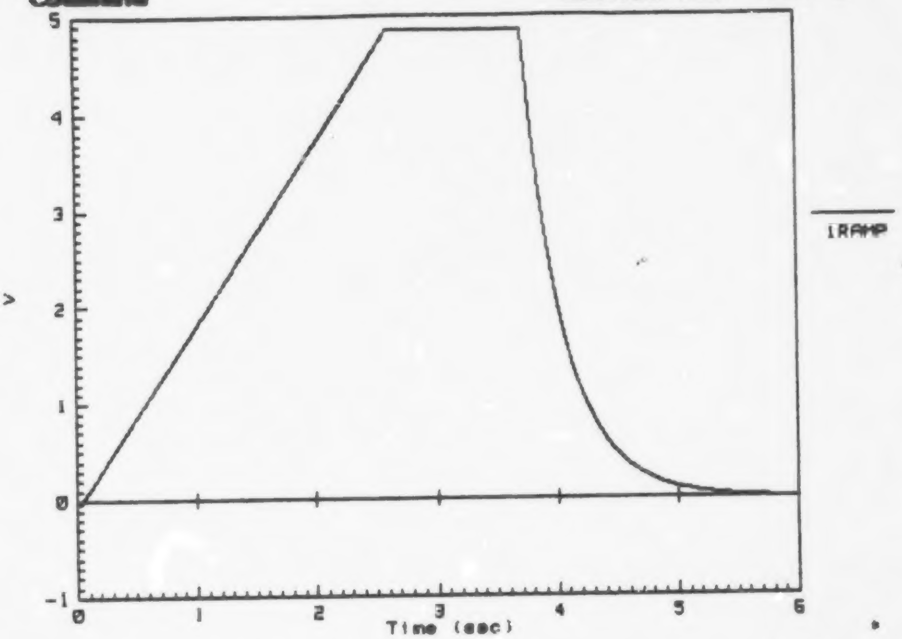
*** Window 1 ***
Test duration .................. 6 Second(s)
AD-200 sample period............ 16.1 Micro-second(s)
Sample rate, aggregate ......... 62111 Hz.
Sample rate per channel ........ 3881 Hz.
Number of samples per channel .. 23292 words.
Total number of samples ........ 745344 words.
Trigger source ................. INTERNAL
Number of cards ................ 2
Number of channels per card .... 16
Total number of channels ....... 32
```

Transducer table for test #PBT08_HDR

```
14750 Card1:!
14760   !-----|--|--|--|--|----|--------|--------|-------|------|---------|
14770   !Card |Ch|SW|HW|Ex|Mode| Gain   | Offset | Units |  Ch  |  Serial |
14780   ! no. |no|gn|gn|gn|    | (eng/V)|  (V)   | (/V)  |  Id  |  Number |
14790   !-----|--|--|--|--|----|--------|--------|-------|------|---------|
14800   DATA 1, 1, 1, 1, 1, "S",  107.29,  2.9028,   "mm", "BD1",  "A33380"
14810   DATA 1, 2, 1, 1, 1, "S",  107.42,  2.0923,   "mm", "BD2",  "A22090"
14820   DATA 1, 3, 1, 1, 1, "S",  107.42,  2.4609,   "mm", "BD3",  "A22091"
14830   DATA 1, 4, 1, 1, 1, "S",  6.8529,  0.0879,  "MPa","APR1",    "5817"
14840   DATA 1, 5, 1, 1, 1, "S",  6.8586,  0.0049,  "MPa","APE1",    "4986"
14850   DATA 1, 6, 1, 1, 1, "S",  6.8792,  0.0562,  "MPa","APR2",    "5723"
14860   DATA 1, 7, 1, 1, 1, "S",  6.8636,  0.0708,  "MPa","APE2",    "5815"
14870   DATA 1, 8, 1, 1, 1, "S",  6.8643,  0.0806,  "MPa","APR3",    "5883"
14880   DATA 1, 9, 1, 1, 1, "S",  6.8531,  0.0562,  "MPa","APE3",    "5885"
14890   DATA 1,10, 1, 1, 1, "S",  13.709,  0.0757,  "MPa", "BP1",    "5887"
14900   DATA 1,11, 1, 1, 1, "S",  13.712,  0.1025,  "MPa", "BP2",    "5773"
14910   DATA 1,12, 1, 1, 1, "S",  13.734,  0.0806,  "MPa", "BP3",    "5892"
14920   DATA 1,13, 1, 1, 1, "S",  13.731,  0.0708,  "MPa", "BP4",    "5889"
14930   DATA 1,14, 1, 1, 1, "S",  13.717,  0.0635,  "MPa", "BP5",    "5891"
14940   DATA 1,15, 1, 1, 2, "S",     1.0,       0,  "  V","RAMP",  "      "
14950   DATA 1,16, 1, 1, 1, "S",  1000.0,       0,   "uE","BR1B",  "      "
14960 Card2:!
14970   DATA 2, 1 ,1, 1, 2, "S",  53.906,  1.3525,   "mm", "AD1",  "A22091"
14980   DATA 2, 2, 1, 1, 2, "S",  53.634,  1.3379,   "mm", "AD2",  "A33381"
14990   DATA 2, 3, 1, 1, 2, "S",  53.608,  1.4599,   "mm", "AD3",  "A33382"
15000   DATA 2, 4, 1, 1, 1, "S",  1000.0,       0,   "uE","BR1A",  "      "
15010   DATA 2, 5, 1, 1, 1, "S",  1000.0,       0,   "uE","BR2A",  "      "
15020   DATA 2, 6, 1, 1, 1, "S",  1000.0,       0,   "uE","FSG3",  "      "
15030   DATA 2, 7, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS7",  "      "
15040   DATA 2, 8, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS8",  "      "
15050   DATA 2, 9, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS9",  "      "
15060   DATA 2,10, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS1",  "      "
15070   DATA 2,11, 1, 1, 1, "S",  1000.0,       0,   "uE","BR2B",  "      "
15080   DATA 2,12, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS3",  "      "
15090   DATA 2,13, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS4",  "      "
15100   DATA 2,14, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS2",  "      "
15110   DATA 2,15, 1, 1, 1, "S",  1000.0,       0,   "uE","BR2C",  "      "
15120   DATA 2,16, 1, 1, 1, "S",  1000.0,       0,   "uE","BR1C",  "      "
15130   !-----|--|--|--|--|----|--------|--------|-------|------|---------|
15140   !Card |Ch|SW|HW|Ex|Mode| Gain   | Offset | Units |  Ch  |  Serial |
15150   ! no. |no|gn|gn|gn|    | (Eng/V)|  (V)   | (/V)  |  Id  |  Number |
15160   !-----|--|--|--|--|----|--------|--------|-------|------|---------|
15170 End_transducers:!
```

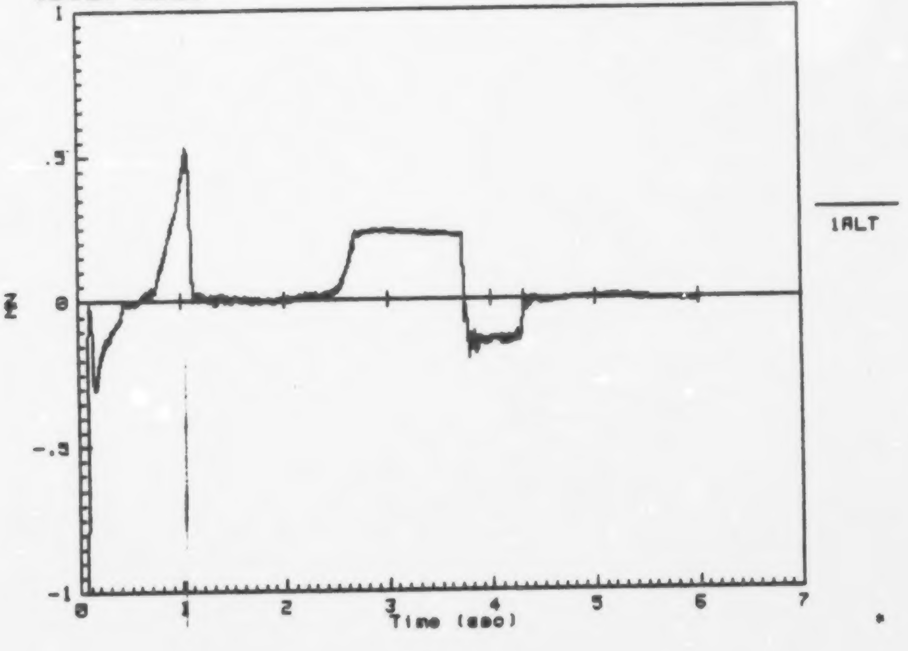
GEOTECHnical Resources Ltd. ANALYSIS DATE:16 May 1988

Command **Series PBT Test 8**



GEOTECHnical Resources Ltd. ANALYSIS DATE:16 May 1988

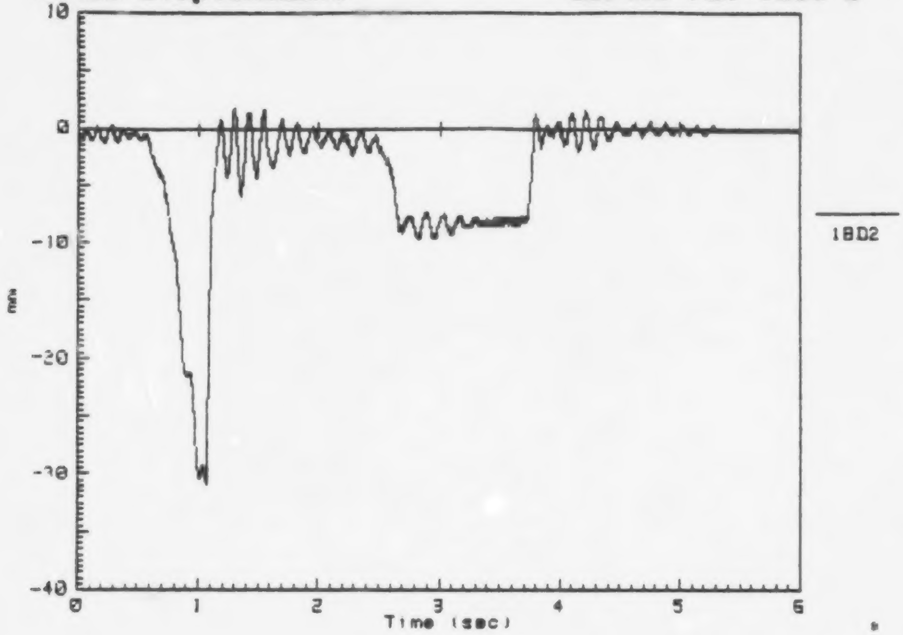
Total Load **Series PBT Test 8**



Peak load
0.55 MN

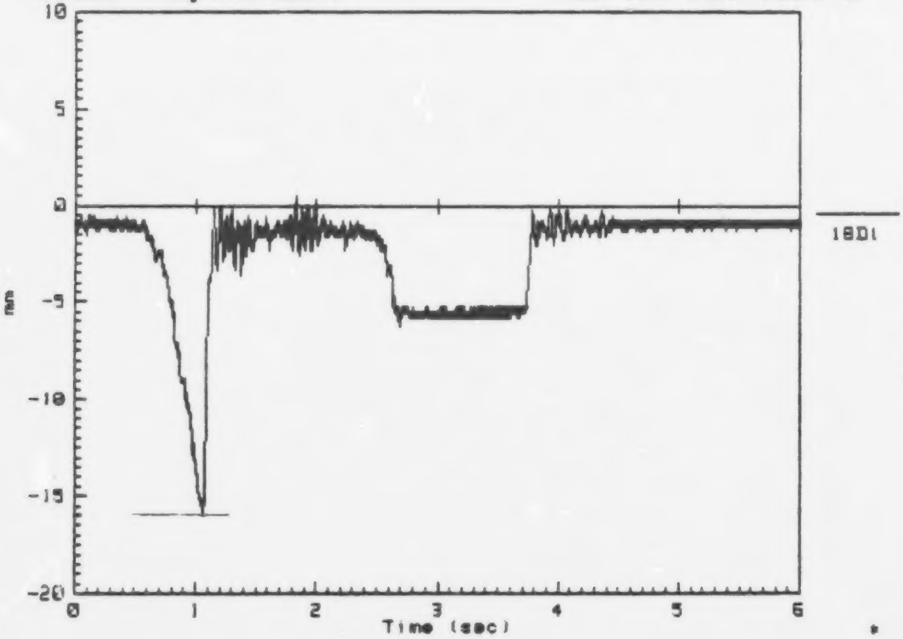
GEOTECHnical Resources Ltd. ANALYSIS DATE: 16 May 1988

Blade Displacement **Series PBT Test 8**



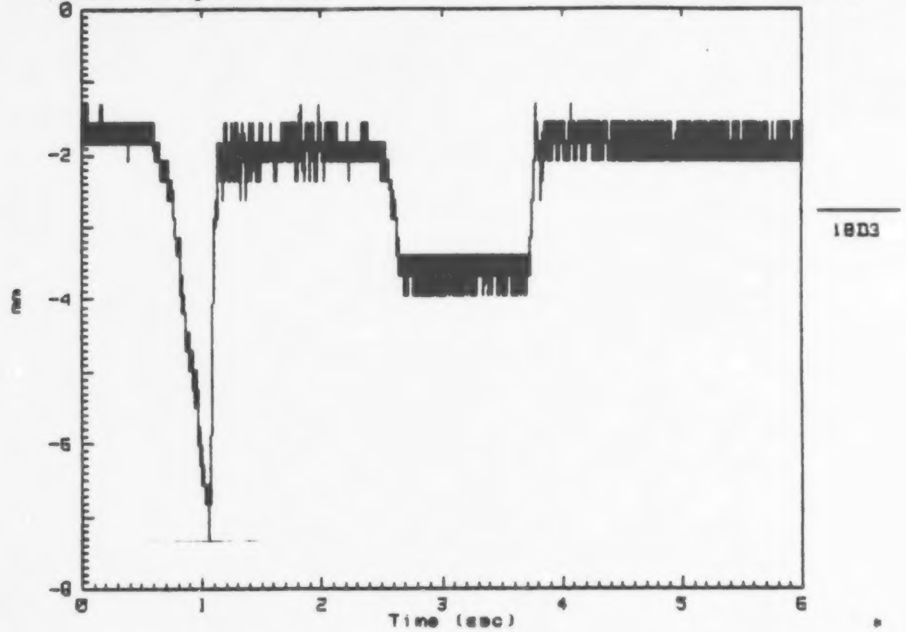
GEOTECHnical Resources Ltd. ANALYSIS DATE: 16 May 1988

Blade Displacement **Series PBT Test 8**



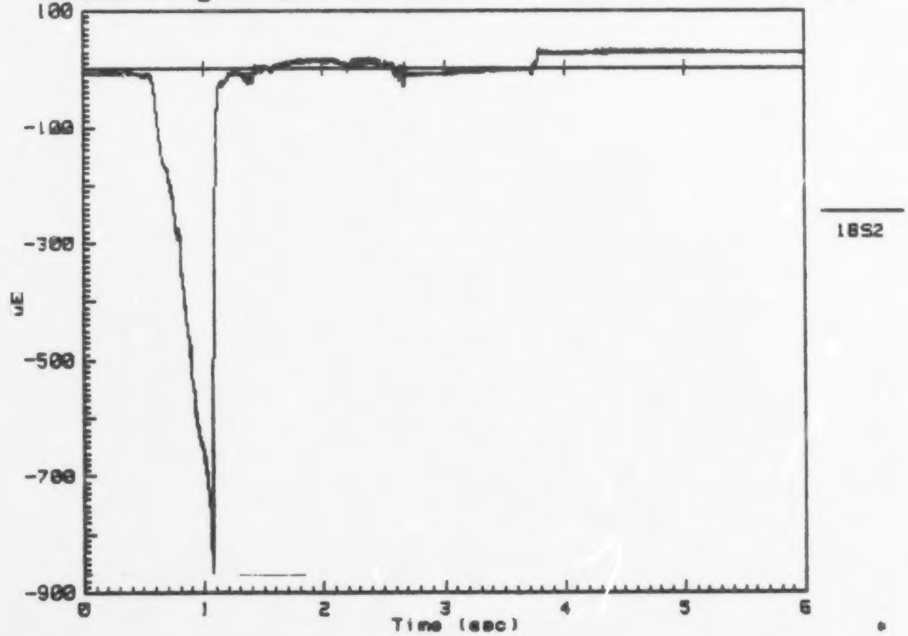
GEOTECHnical Resources Ltd. ANALYSIS DATE:16 May 1988

Blade Displacement **Series PBT Test 0**



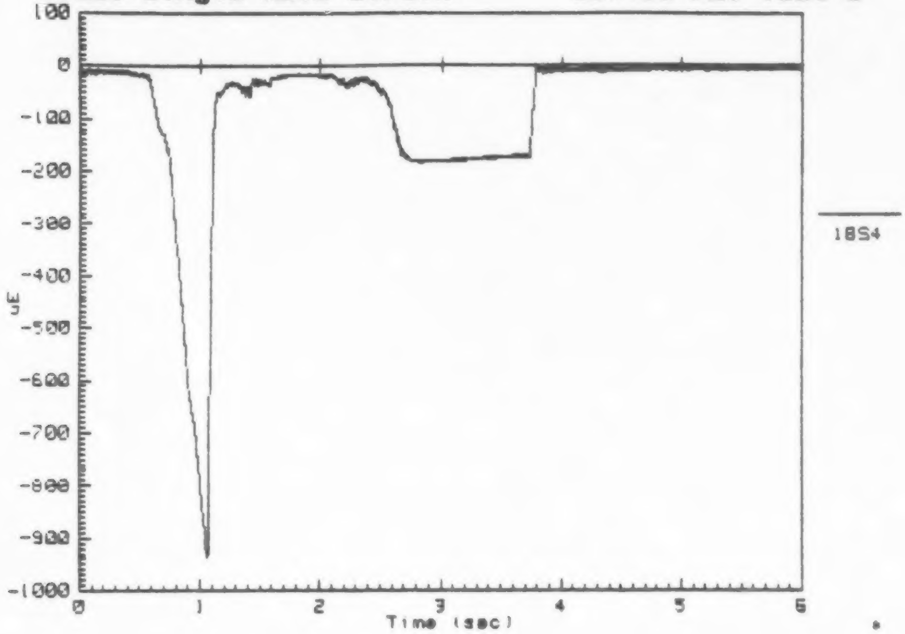
GEOTECHnical Resources Ltd. ANALYSIS DATE:16 May 1988

Blade Single-Axis Strain **Series PBT Test 0**



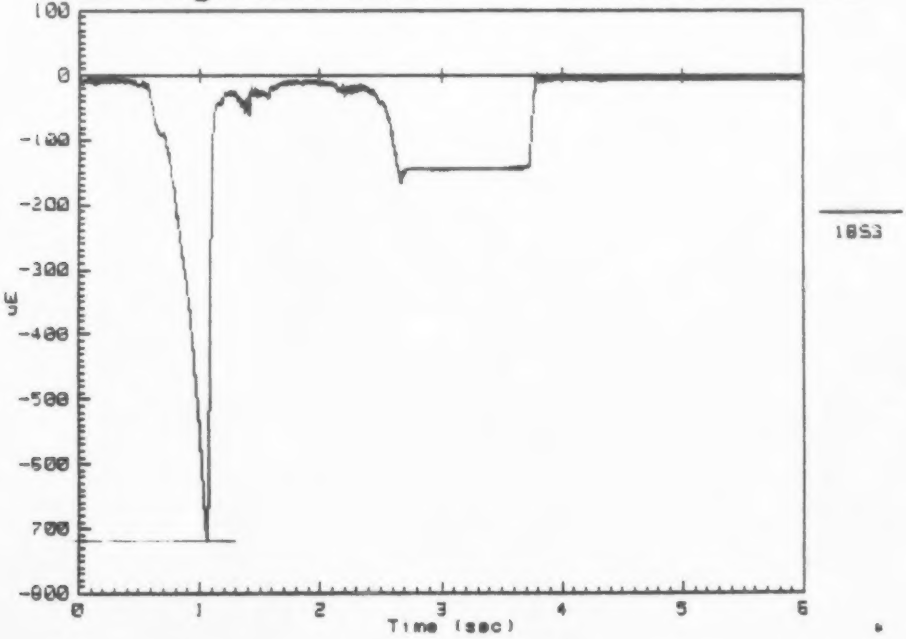
GEOTECHnical Resources Ltd. ANALYSIS DATE: 16 May 1988

Blade Single-Axis Strain **Series PBT Test 8**



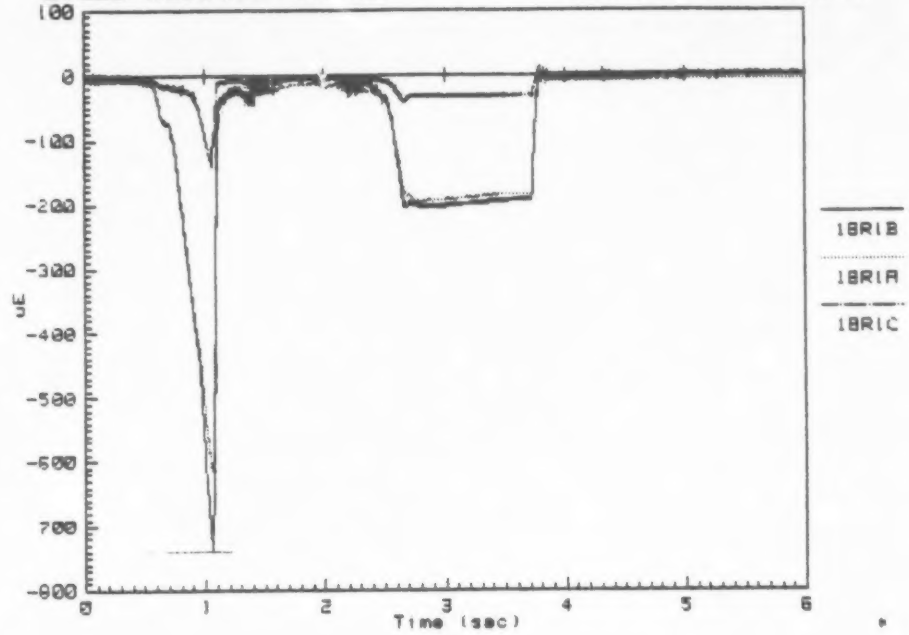
GEOTECHnical Resources Ltd. ANALYSIS DATE: 16 May 1988

Blade Single-Axis Strain **Series PBT Test 8**



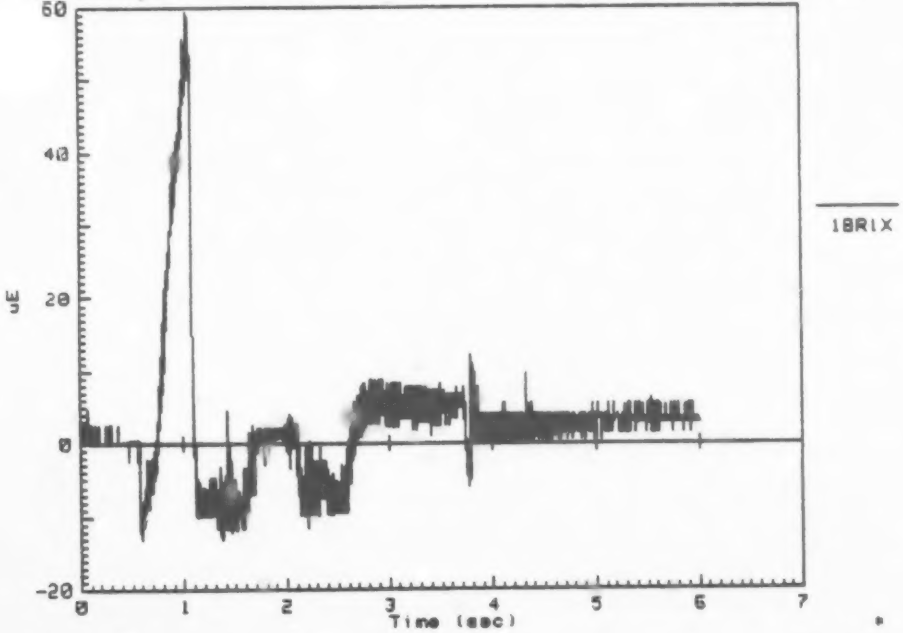
GEOTECHnical Resources Ltd.   ANALYSIS DATE:16 May 1988

Blade Rosette Strain   **Series PBT Test 8**



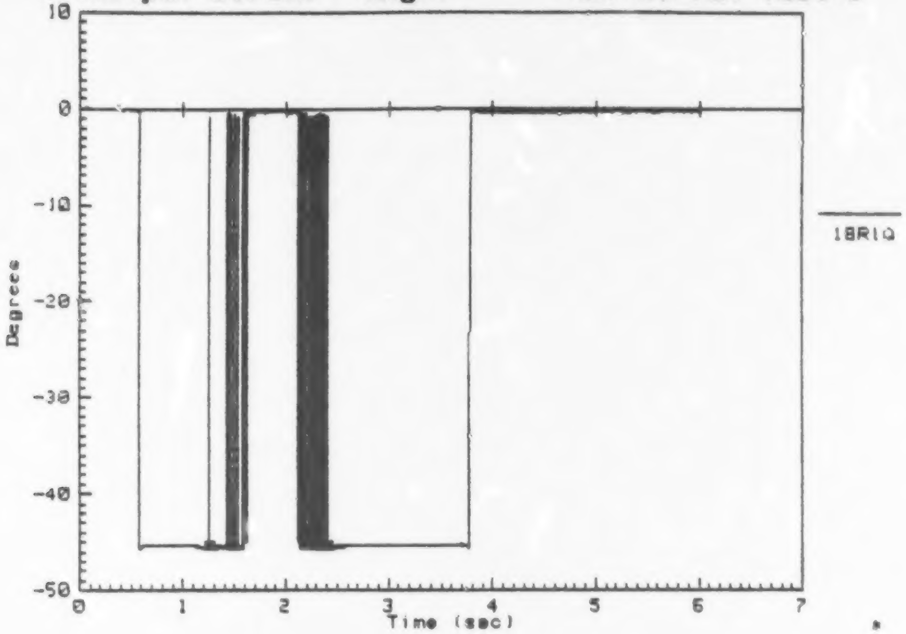
GEOTECHnical Resources Ltd.   ANALYSIS DATE:16 May 1988

Principal Strain - X   **Series PBT Test 8**



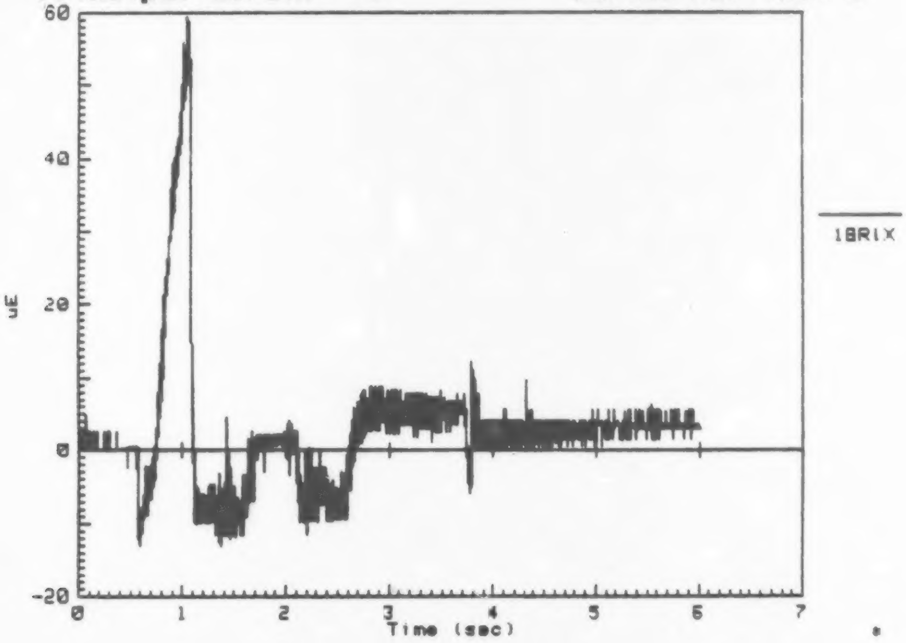
GEOTECHnical Resources Ltd. ANALYSIS DATE: 16 May 1988

Principal strain - Angle **Series PBT Test 8**



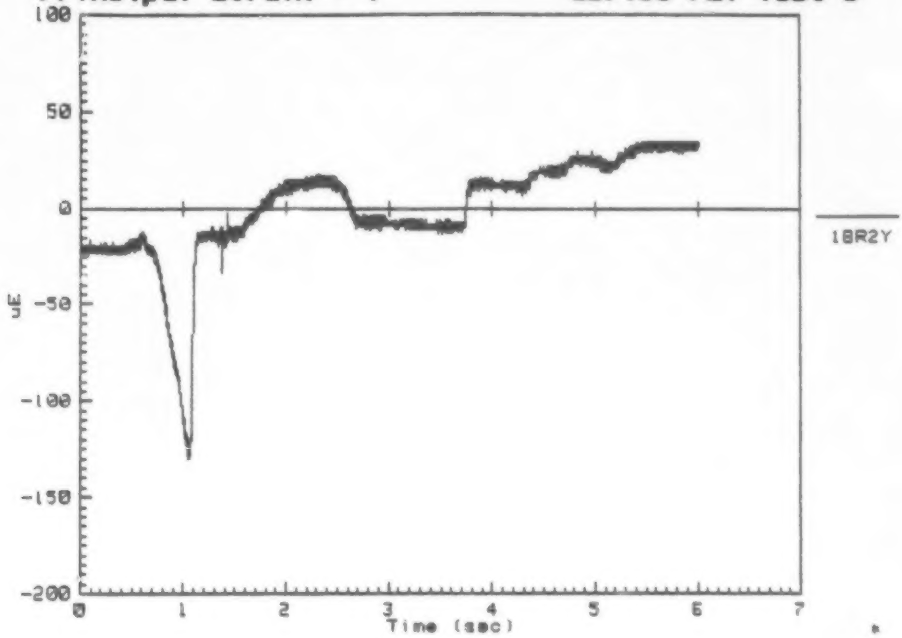
GEOTECHnical Resources Ltd. ANALYSIS DATE: 16 May 1988

Principal Strain - X **Series PBT Test 8**



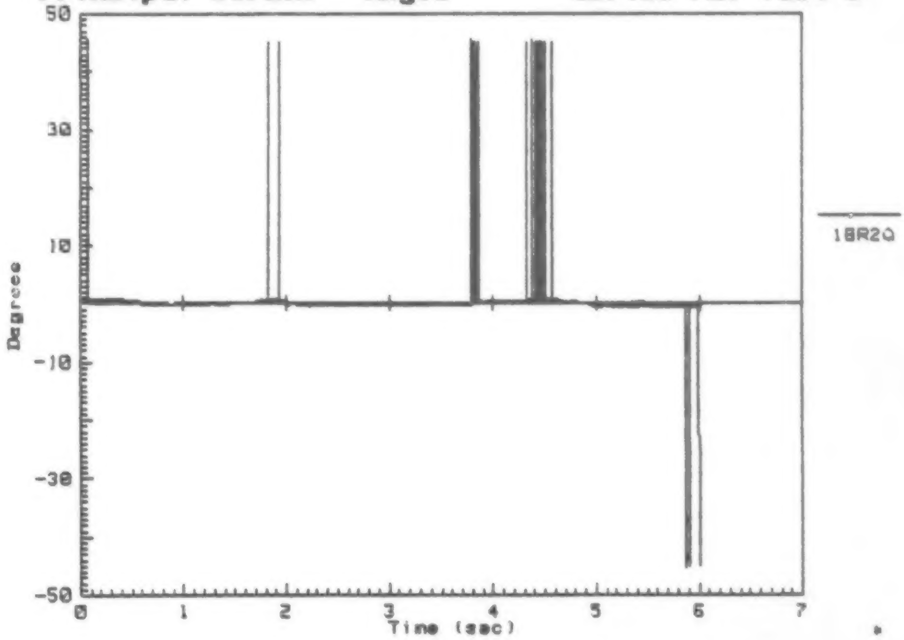
GEOTECHnical Resources Ltd. ANALYSIS DATE:16 May 1988

Principal Strain - Y **Series PBT Test 8**



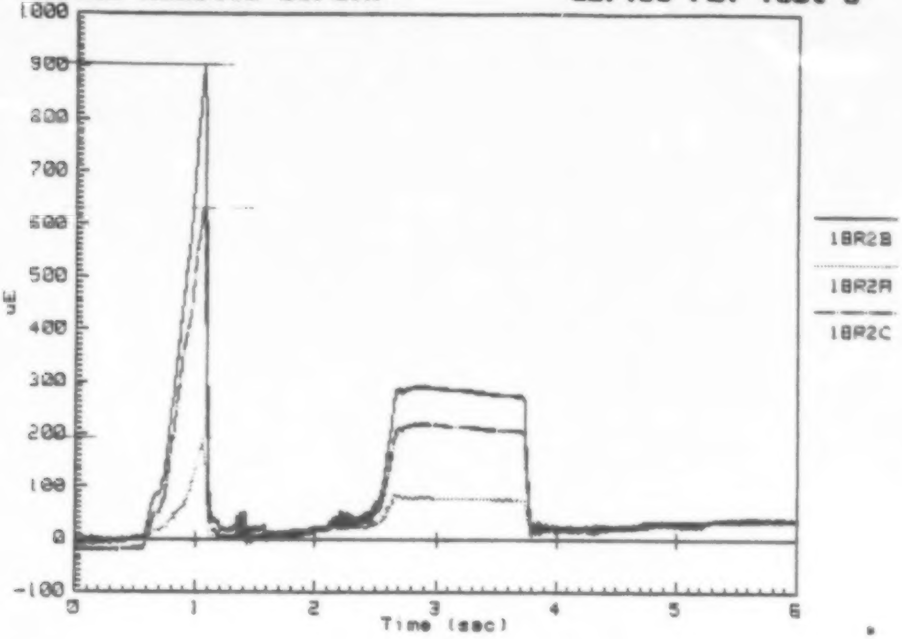
GEOTECHnical Resources Ltd. ANALYSIS DATE:16 May 1988

Principal strain - Angle **Series PBT Test 8**



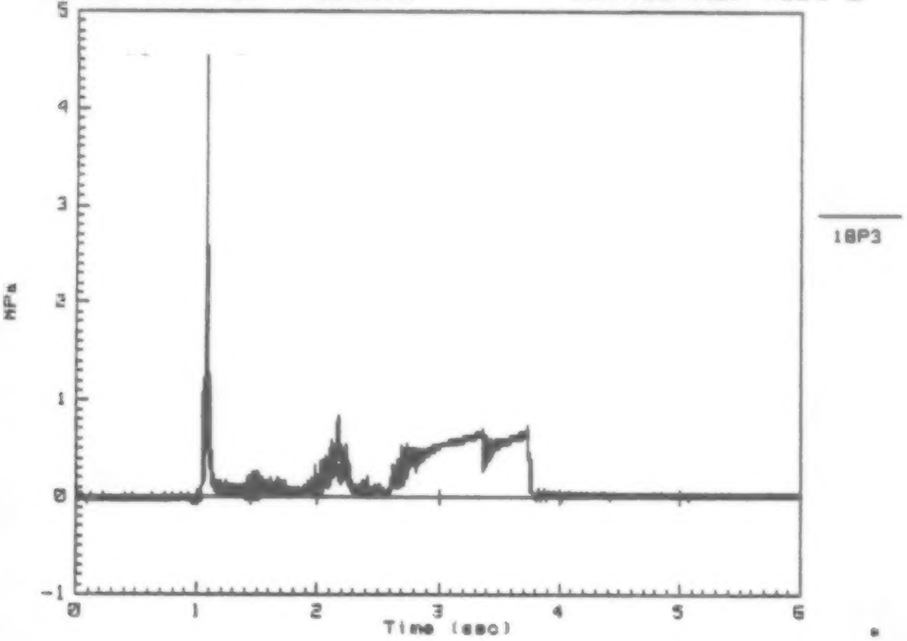
GEOTECHnical Resources Ltd. ANALYSIS DATE:16 May 1988

Blade Rosette Strain **Series PBT Test 8**



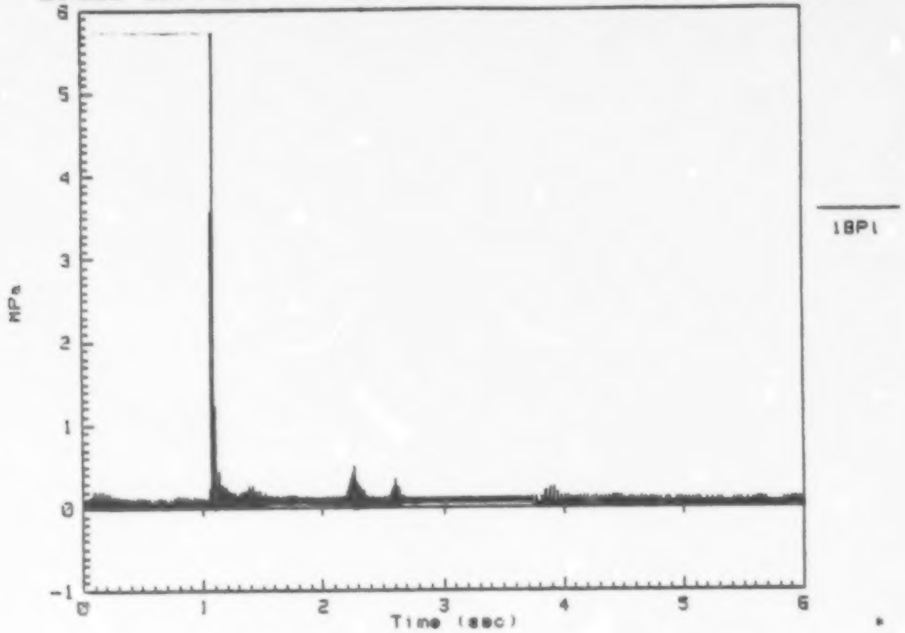
GEOTECHnical Resources Ltd. ANALYSIS DATE:16 May 1988

Blade Surface Pressure **Series PBT Test 8**



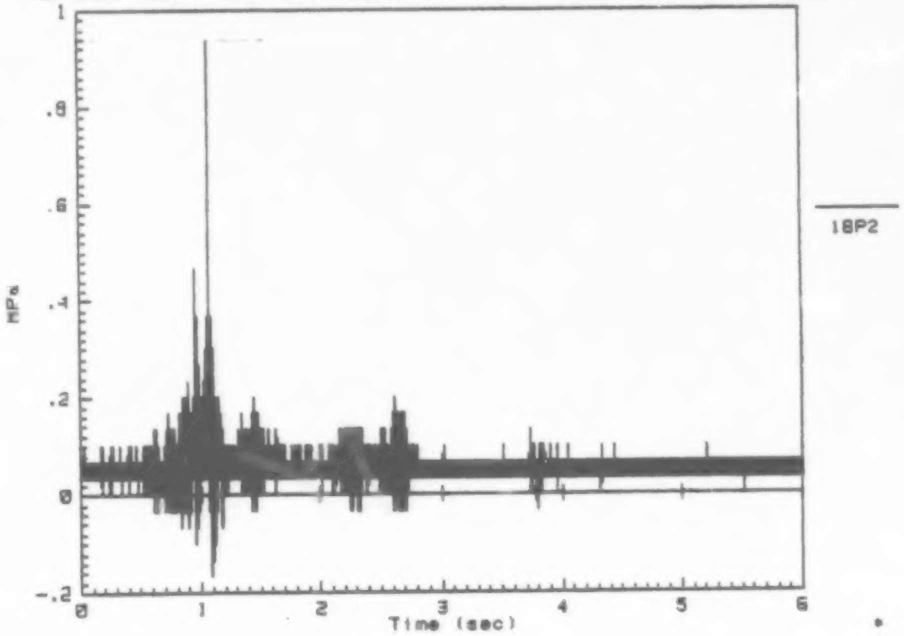
GEOTECHnical Resources Ltd. ANALYSIS DATE: 16 May 1988

Blade Surface Pressure **Series PBT Test 8**



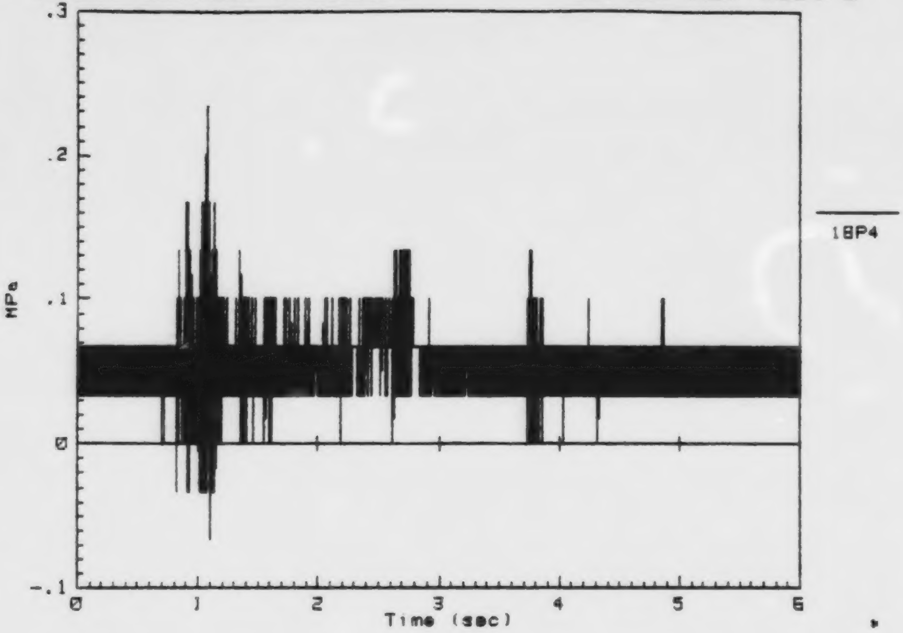
GEOTECHnical Resources Ltd. ANALYSIS DATE: 16 May 1988

Blade Surface Pressure **Series PBT Test 8**



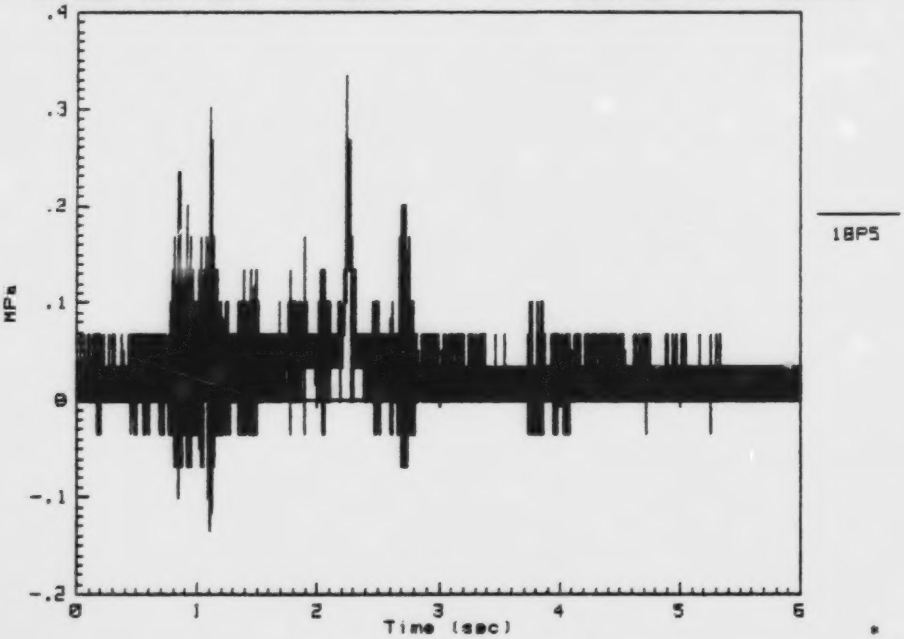
GEOTECHnical Resources Ltd. ANALYSIS DATE:16 May 1988

Blade Surface Pressure **Series PBT Test 8**



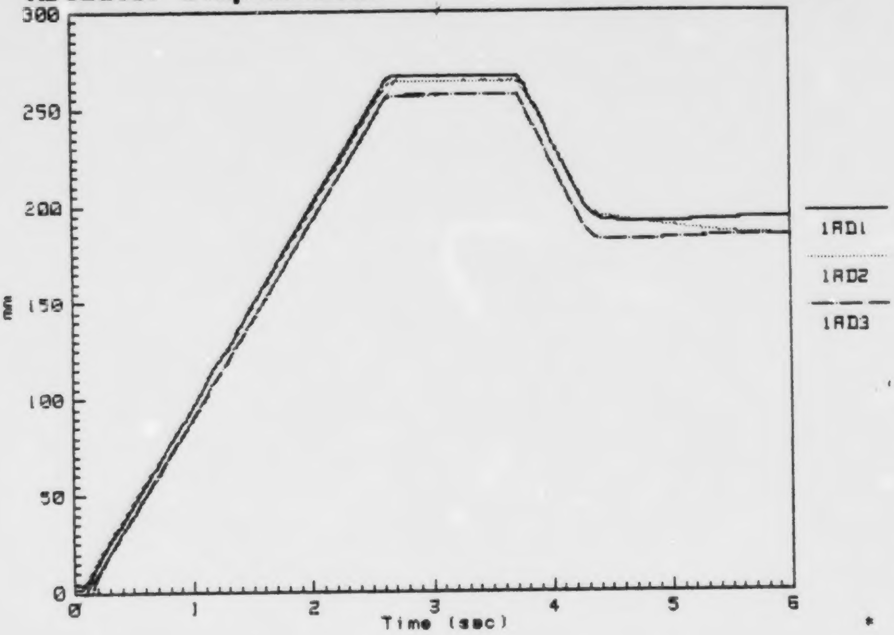
GEOTECHnical Resources Ltd. ANALYSIS DATE:16 May 1988

Blade Surface Pressure **Series PBT Test 8**



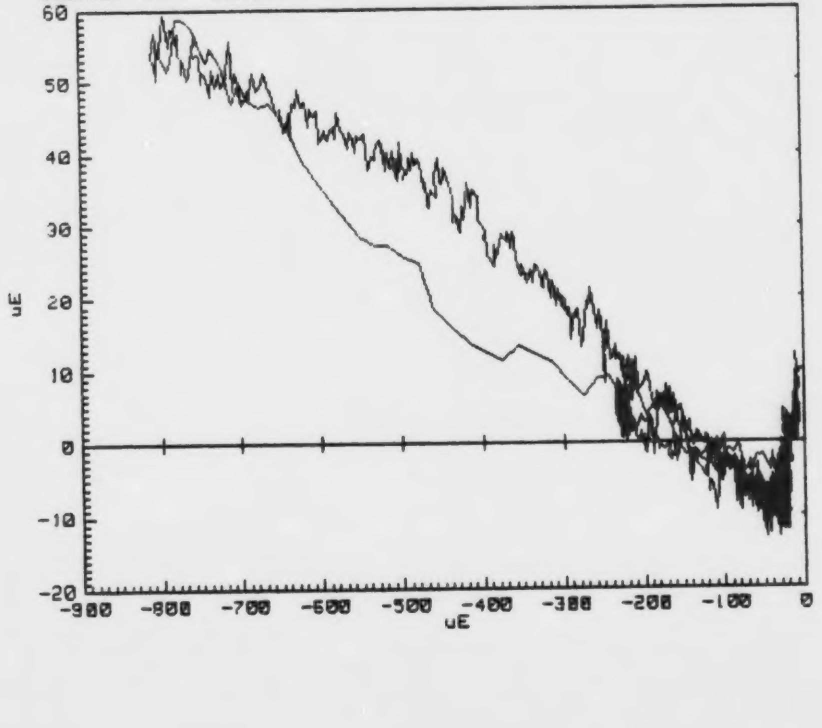
GEOTECHnical Resources Ltd. ANALYSIS DATE:16 May 1988

Actuator Displacement **Series PBT Test 8**



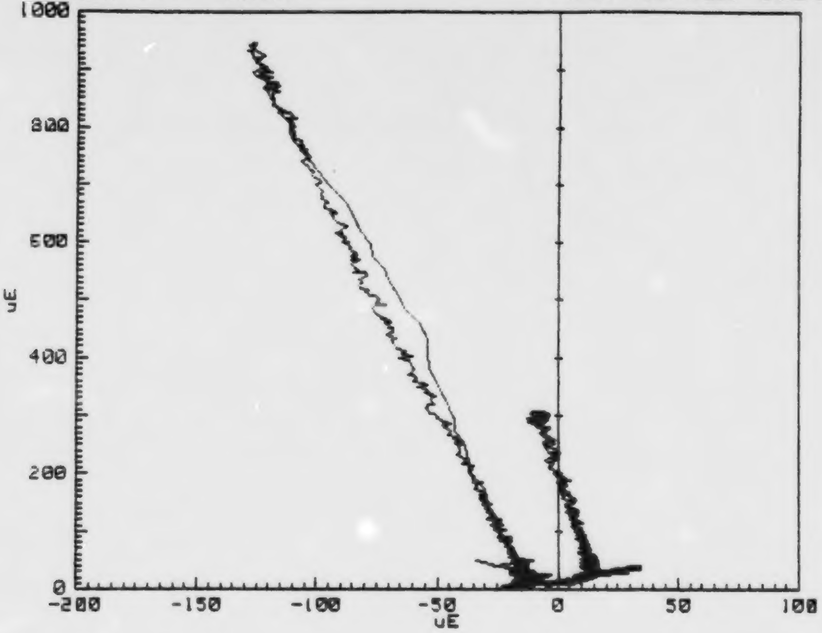
GEOTECHnical Resources Ltd. ANALYSIS DATE:16 May 1988

1BR1X vs. 1BR1Y **Series PBT Test 8**



GEOTECHnical Resources Ltd.   ANALYSIS DATE:16 May 1988

1BR2X vs. 1BR2Y   **Series PBT Test 8**



GEOTECHnical resources ltd
PROP BUSTERS
PROJECT NUMBER: 9448

```
Date: 17 May 1988
Time: 09:10:16

Test series...... PBT
Test number...... 9

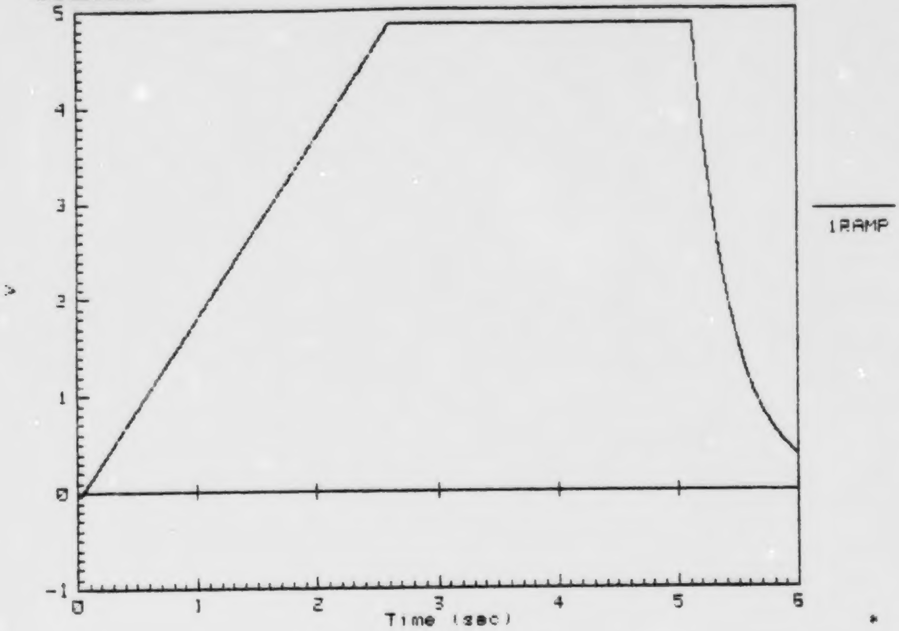
*** Window 1 ***
Test duration .................. 6 Second(s)
AD-200 sample period............ 16.1 Micro-second(s)
Sample rate, aggregate ......... 62111 Hz.
Sample rate per channel ........ 3881 Hz.
Number of samples per channel .. 23292 words.
Total number of samples ........ 745344 words.
Trigger source ................. INTERNAL
Number of cards ................ 2
Number of channels per card .... 16
Total number of channels ....... 32
```

Transducer table for test #PBT09_HDR

```
14750 Card1:!
14760   !-----|--|--|--|--|----|---------|---------|--------|------|----------|
14770   !Card |Ch|SW|HW|Ex|Mode|  Gain   | Offset  | Units  |  Ch  |  Serial  |
14780   ! no. |no|gn|gn|gn|    | (eng/V)|  (V)    | (/V)   |  Id  |  Number  |
14790   !-----|--|--|--|--|----|---------|---------|--------|------|----------|
14800   DATA 1, 1, 1, 1, 1, "S",  107.29,  2.9028,   "mm", "BD1",  "A33380"
14810   DATA 1, 2, 1, 1, 1, "S",  107.42,  2.0923,   "mm", "BD2",  "A22090"
14820   DATA 1, 3, 1, 1, 1, "S",  107.42,  2.4609,   "mm", "BD3",  "A22091"
14830   DATA 1, 4, 1, 1, 1, "S",  6.8529,  0.0879,  "MPa","APR1",    "5817"
14840   DATA 1, 5, 1, 1, 1, "S",  6.8586,  0.0049,  "MPa","APE1",    "4986"
14850   DATA 1, 6, 1, 1, 1, "S",  6.8792,  0.0562,  "MPa","APR2",    "5723"
14860   DATA 1, 7, 1, 1, 1, "S",  6.8636,  0.0708,  "MPa","APE2",    "5815"
14870   DATA 1, 8, 1, 1, 1, "S",  6.8643,  0.0806,  "MPa","APR3",    "5883"
14880   DATA 1, 9, 1, 1, 1, "S",  6.8531,  0.0562,  "MPa","APE3",    "5885"
14890   DATA 1,10, 1, 1, 1, "S",  13.709,  0.0757,  "MPa", "BP1",    "5887"
14900   DATA 1,11, 1, 1, 1, "S",  13.712,  0.1025,  "MPa", "BP2",    "5773"
14910   DATA 1,12, 1, 1, 1, "S",  13.734,  0.0806,  "MPa", "BP3",    "5892"
14920   DATA 1,13, 1, 1, 1, "S",  13.731,  0.0708,  "MPa", "BP4",    "5889"
14930   DATA 1,14, 1, 1, 1, "S",  13.717,  0.0635,  "MPa", "BP5",    "5891"
14940   DATA 1,15, 1, 1, 2, "S",     1.0,       0,  "  V","RAMP",   "     "
14950   DATA 1,16, 1, 1, 1, "S",  1000.0,       0,   "uE","BR1B",   "     "
14960 Card2:!
14970   DATA 2, 1 ,1, 1, 2, "S",  53.906,  1.3525,   "mm", "AD1",  "A22091"
14980   DATA 2, 2, 1, 1, 2, "S",  53.634,  1.3379,   "mm", "AD2",  "A33381"
14990   DATA 2, 3, 1, 1, 2, "S",  53.608,  1.4599,   "mm", "AD3",  "A33382"
15000   DATA 2, 4, 1, 1, 1, "S",  1000.0,       0,   "uE","BR1A",   "     "
15010   DATA 2, 5, 1, 1, 1, "S",  1000.0,       0,   "uE","BR2A",   "     "
15020   DATA 2, 6, 1, 1, 1, "S",  1000.0,       0,   "uE","FSG3",   "     "
15030   DATA 2, 7, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS7",   "     "
15040   DATA 2, 8, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS8",   "     "
15050   DATA 2, 9, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS9",   "     "
15060   DATA 2,10, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS1",   "     "
15070   DATA 2,11, 1, 1, 1, "S",  1000.0,       0,   "uE","BR2B",   "     "
15080   DATA 2,12, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS3",   "     "
15090   DATA 2,13, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS4",   "     "
15100   DATA 2,14, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS2",   "     "
15110   DATA 2,15, 1, 1, 1, "S",  1000.0,       0,   "uE","BR2C",   "     "
15120   DATA 2,16, 1, 1, 1, "S",  1000.0,       0,   "uE","BR1C",   "     "
15130   !-----|--|--|--|--|----|---------|---------|--------|------|----------|
15140   !Card |Ch|SW|HW|Ex|Mode|  Gain   | Offset  | Units  |  Ch  |  Serial  |
15150   ! no. |no|gn|gn|gn|    | (Eng/V)|  (V)    | (/V)   |  Id  |  Number  |
15160   !-----|--|--|--|--|----|---------|---------|--------|------|----------|
15170 End_transducers:!
```

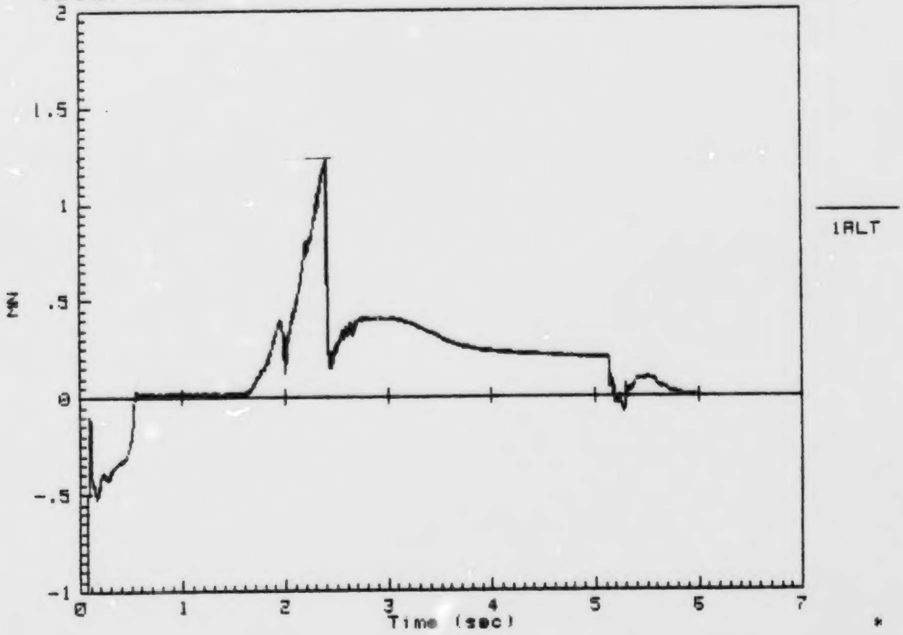
GEOTECHnical Resources Ltd.   ANALYSIS DATE:17 May 1988

Command   **Series PBT Test 9**



GEOTECHnical Resources Ltd.   ANALYSIS DATE:17 May 1988

Total Load   **Series PBT Test 9**



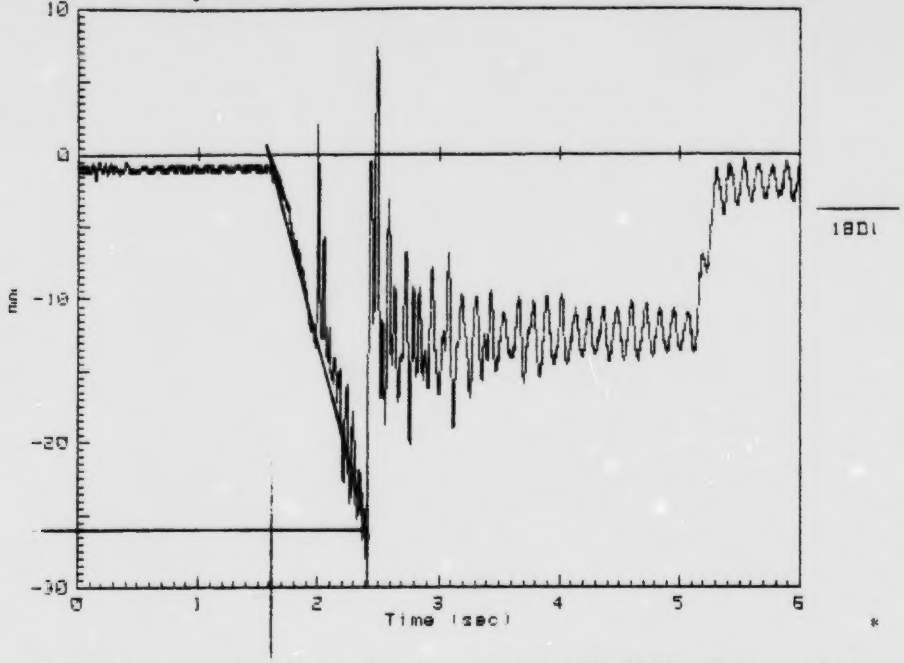
Peak load

≃ 1.24 MN

@ 2.5 [illegible]

GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

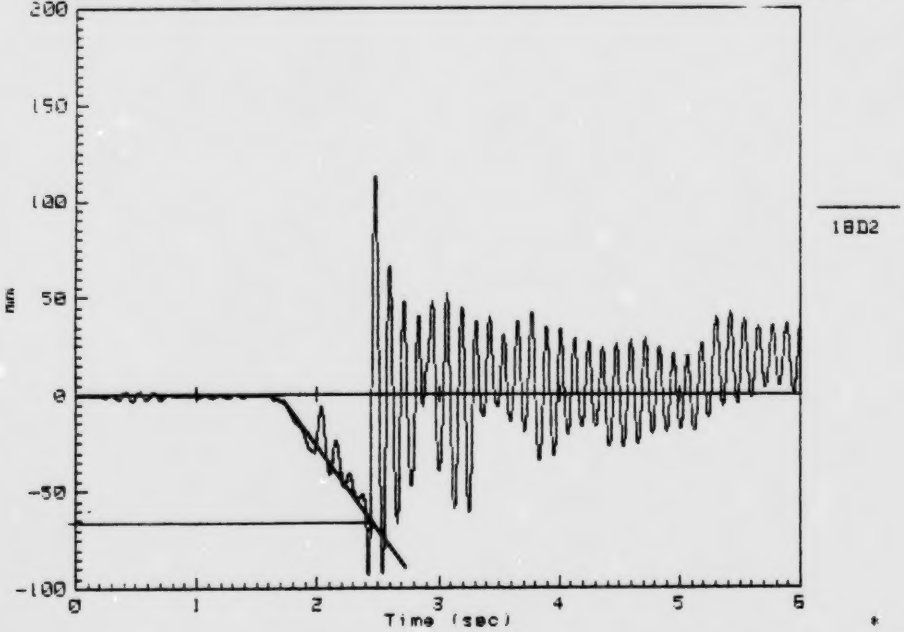
Blade Displacement **Series PBT Test 9**



18D1

GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

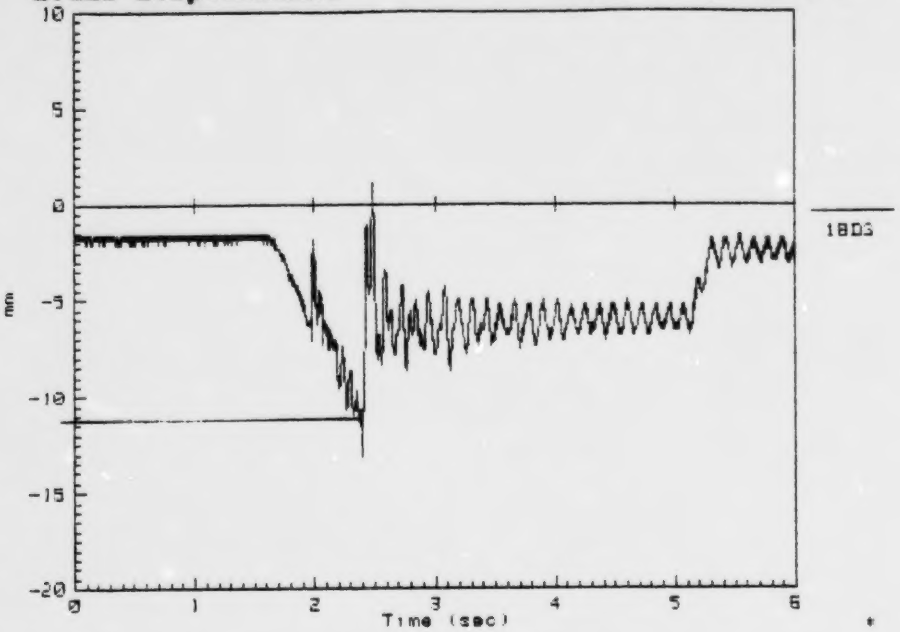
Blade Displacement **Series PBT Test 9**



18D2

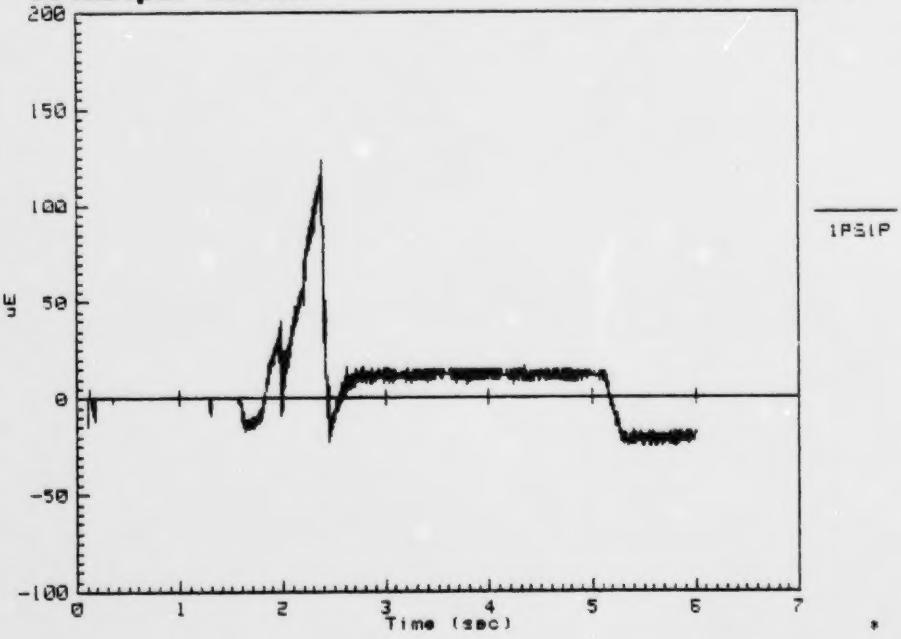
GEOTECHnical Resources Ltd. ANALYSIS DATE: 17 May 1988

Blade Displacement **Series PBT Test 9**



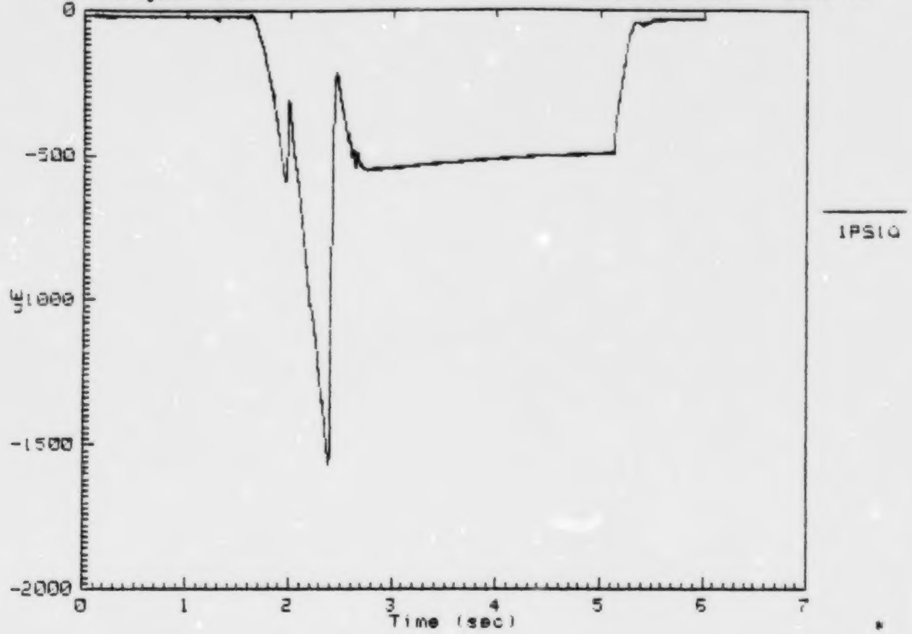
GEOTECHnical Resources Ltd. ANALYSIS DATE: 17 May 1988

Principal Strain - P **Series PBT Test 9**



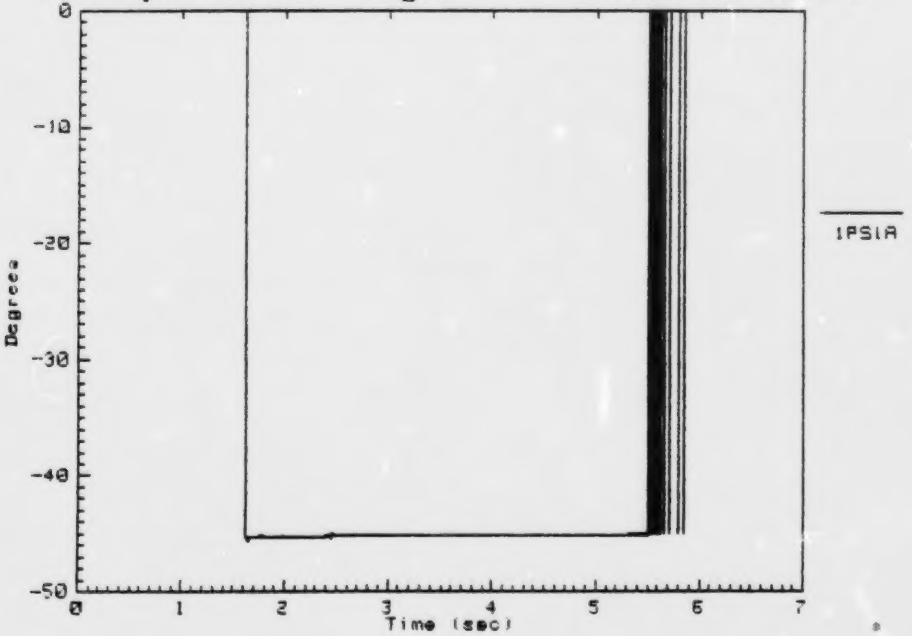
GEOTECHnical Resources Ltd. ANALYSIS DATE: 17 May 1988

Principal Strain – Q **Series PBT Test 9**



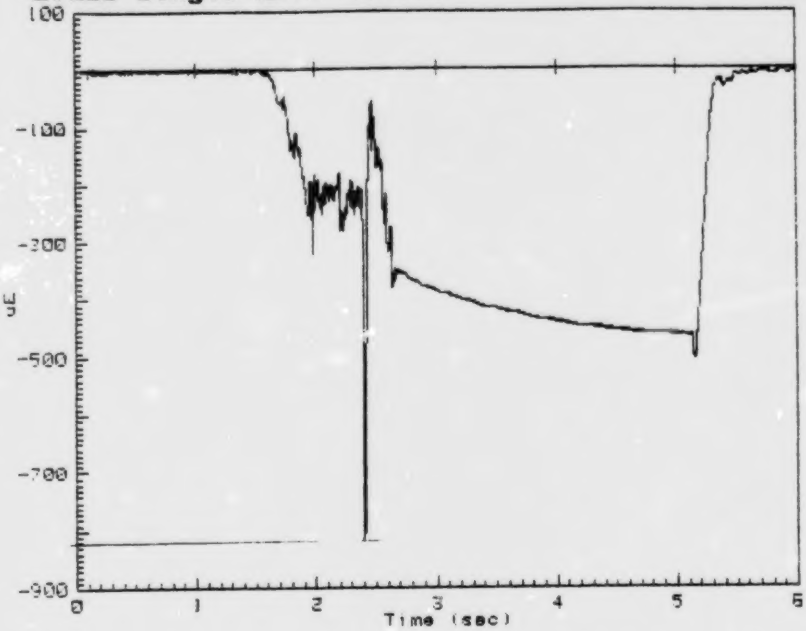
GEOTECHnical Resources Ltd. ANALYSIS DATE: 17 May 1988

Principal strain – Angle **Series PBT Test 9**



GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

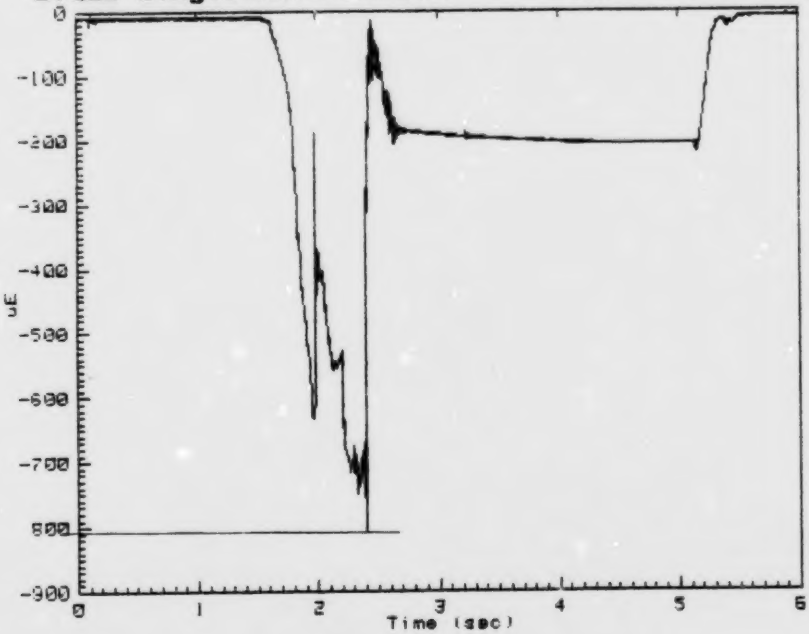
Blade Single-Axis Strain **Series PBT Test 9**



1BS1

GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

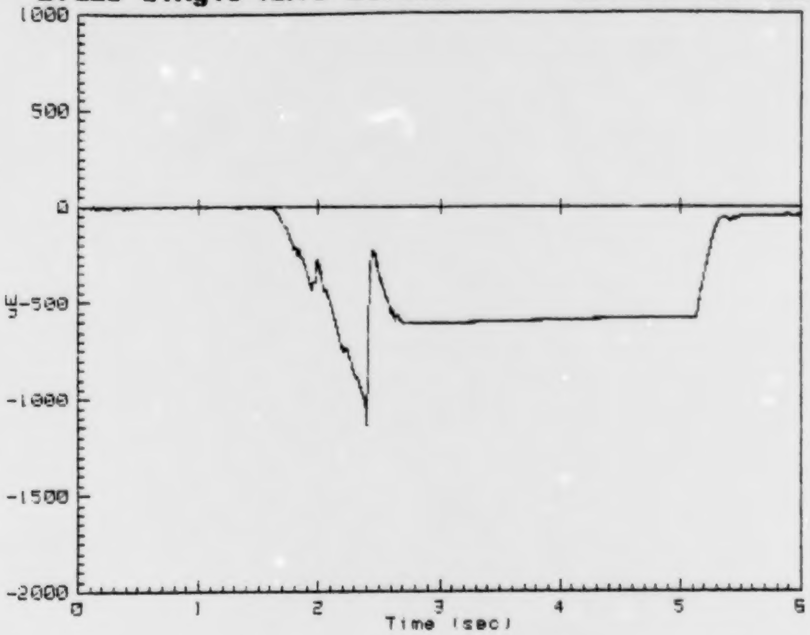
Blade Single-Axis Strain **Series PBT Test 9**



1BS2

GEOTECHnical Resources Ltd. ANALYSIS DATE: 17 May 1988

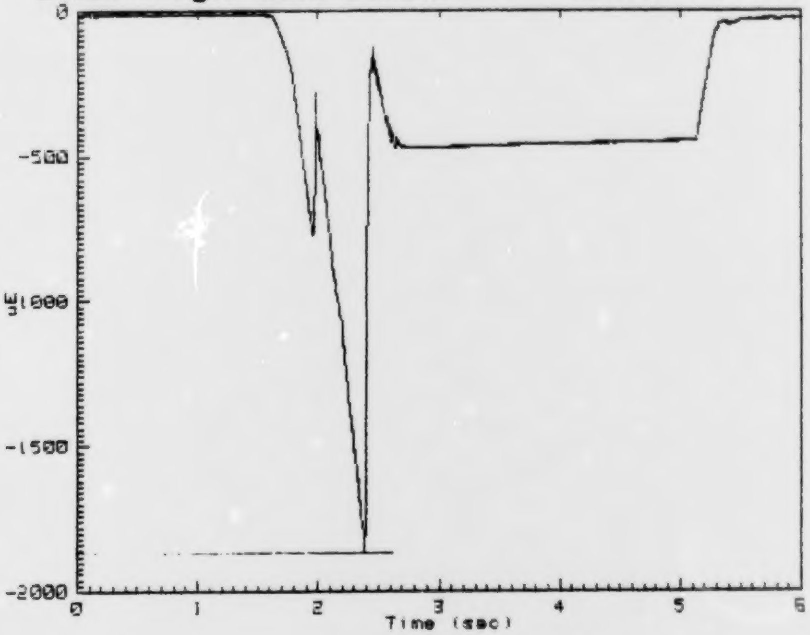
Blade Single-Axis Strain **Series PBT Test 9**



1853

GEOTECHnical Resources Ltd. ANALYSIS DATE: 17 May 1988

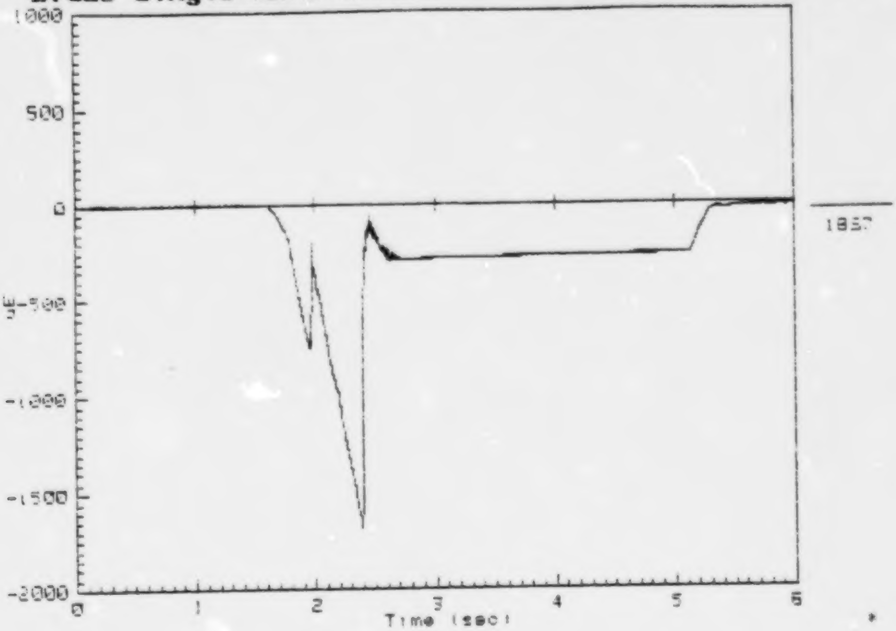
Blade Single-Axis Strain **Series PBT Test 9**



1854

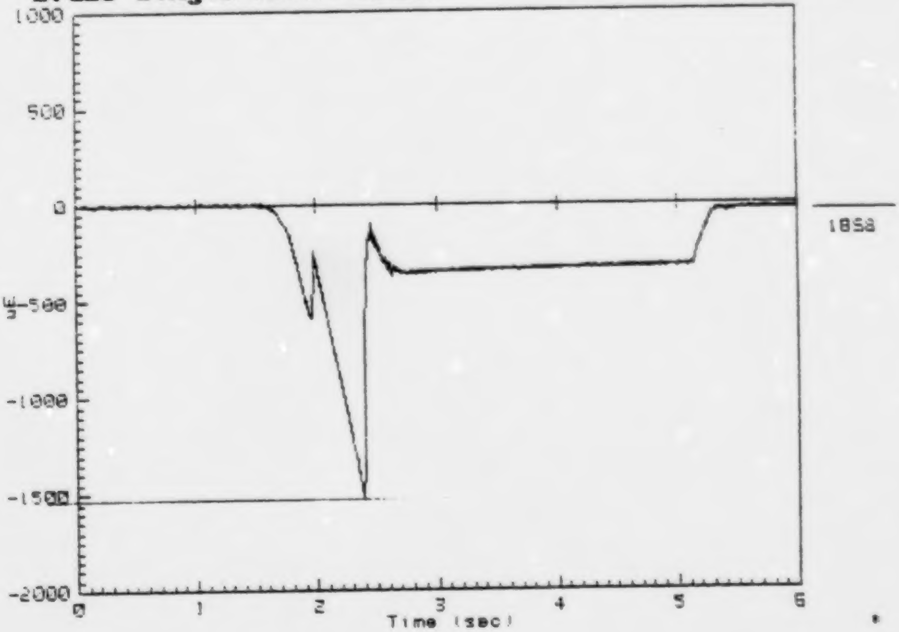
GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

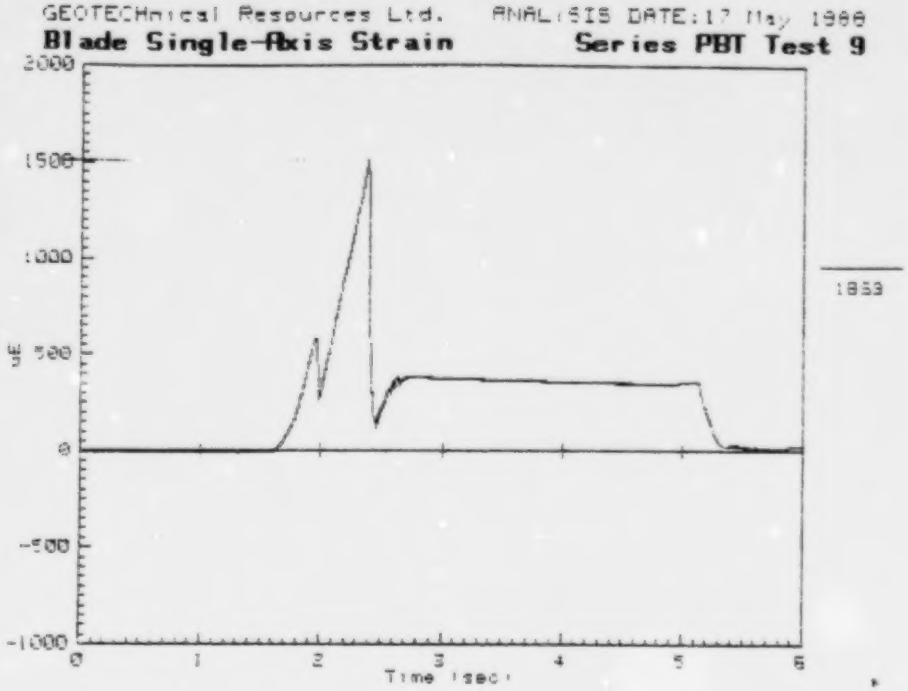
Blade Single-Axis Strain **Series PBT Test 9**



GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

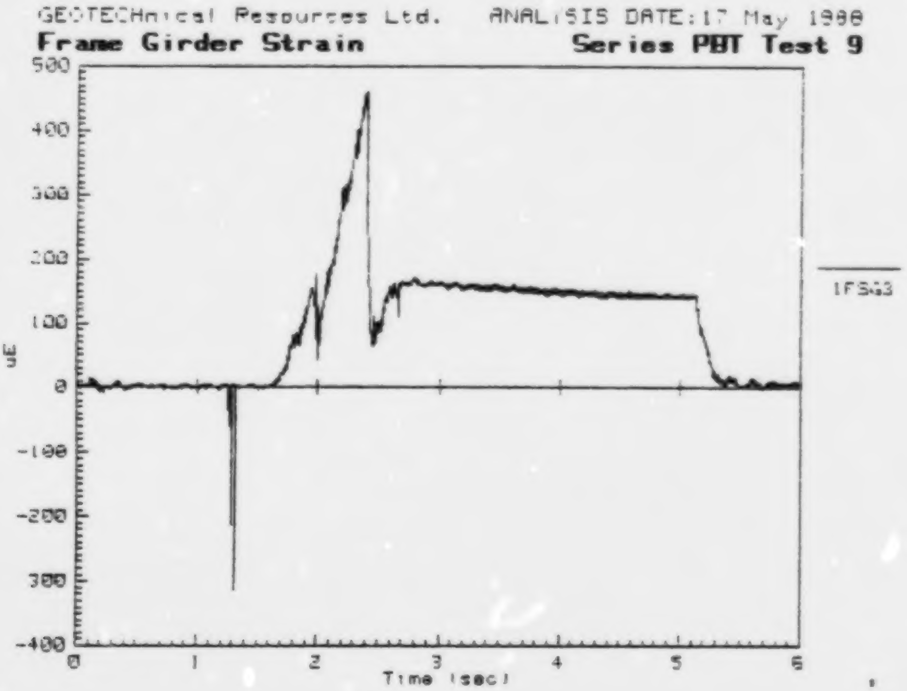
Blade Single-Axis Strain **Series PBT Test 9**





GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

Blade Single-Axis Strain **Series PBT Test 9**

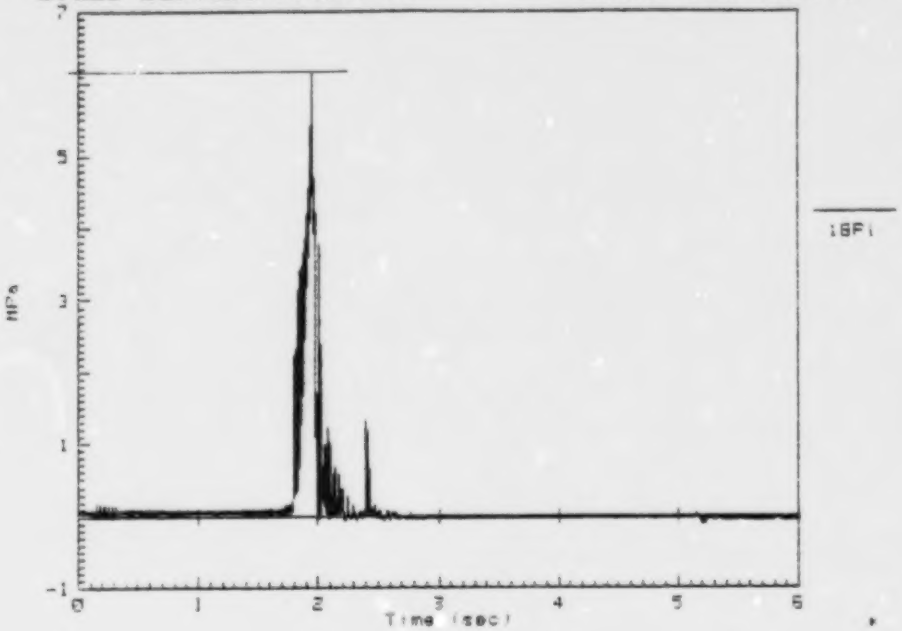


GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

Frame Girder Strain **Series PBT Test 9**

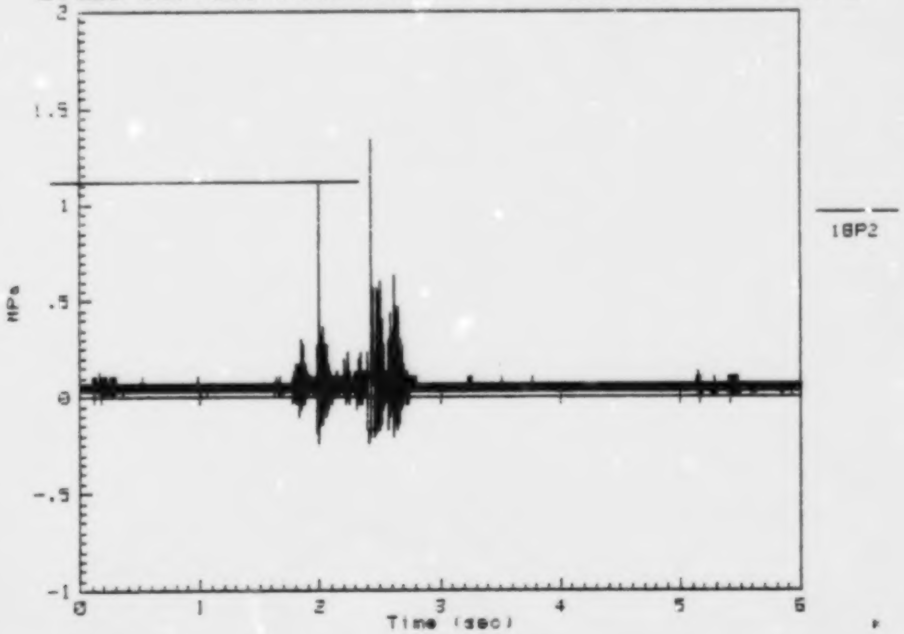
GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

Blade Surface Pressure **Series PBT Test 9**



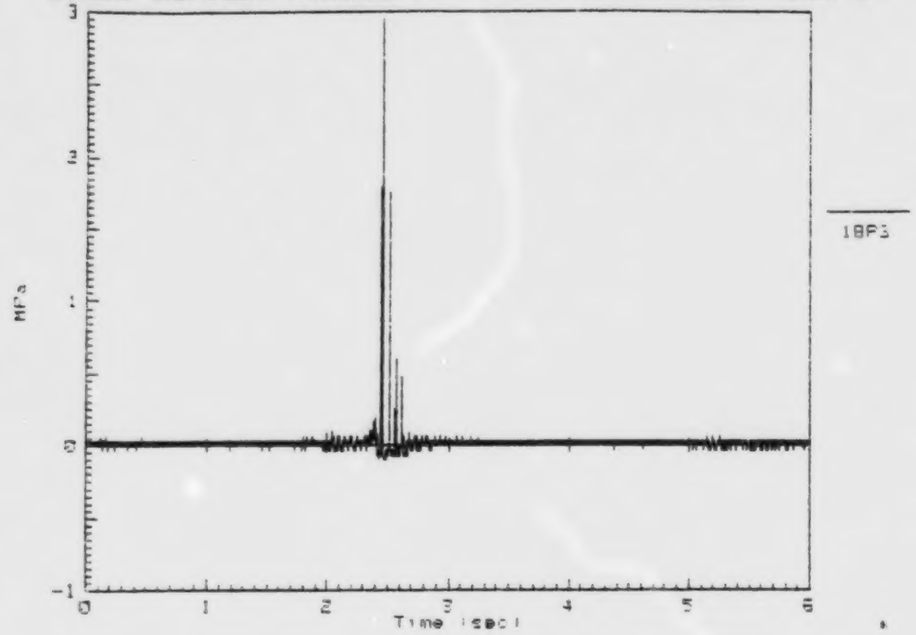
GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

Blade Surface Pressure **Series PBT Test 9**



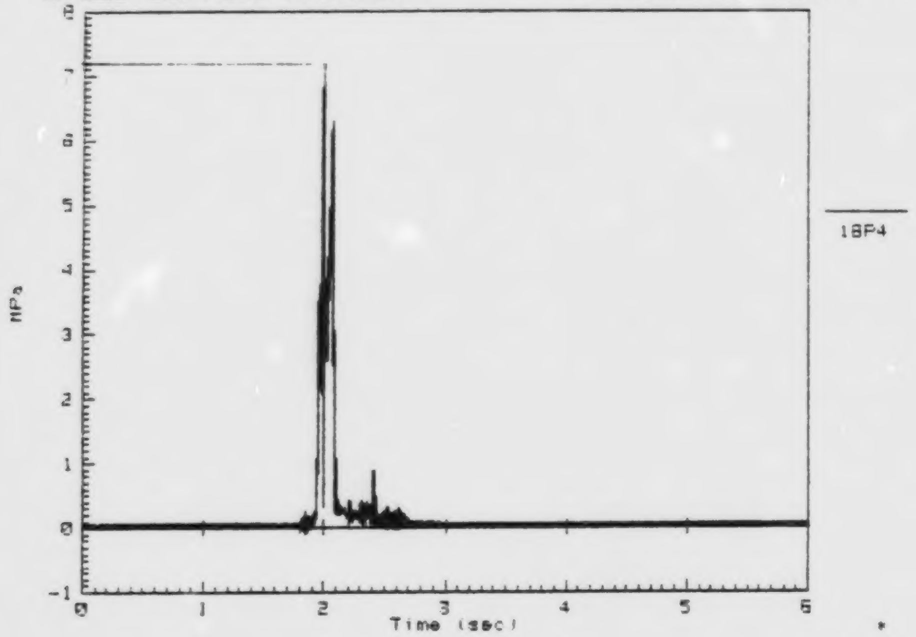
GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

Blade Surface Pressure **Series PBT Test 9**



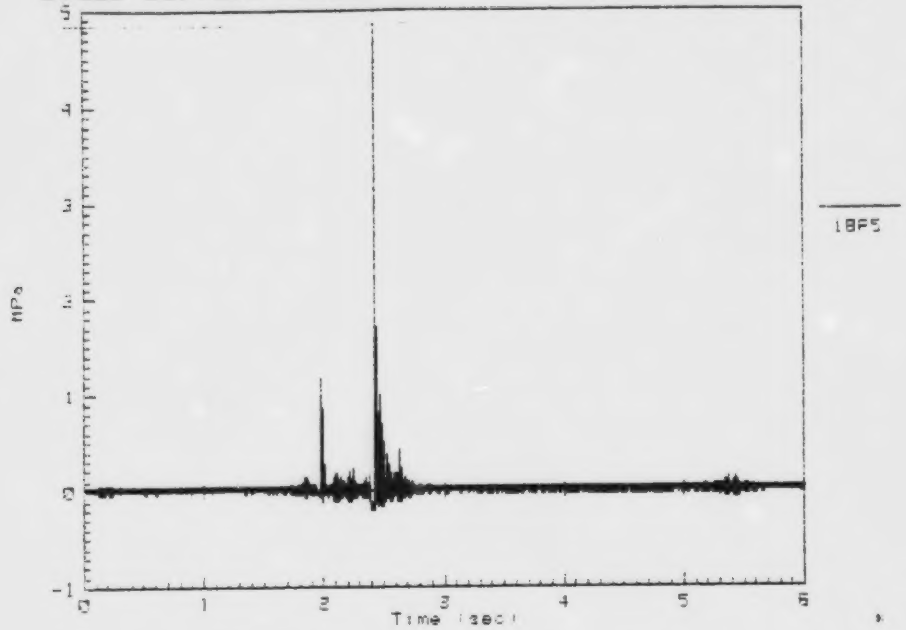
GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

Blade Surface Pressure **Series PBT Test 9**



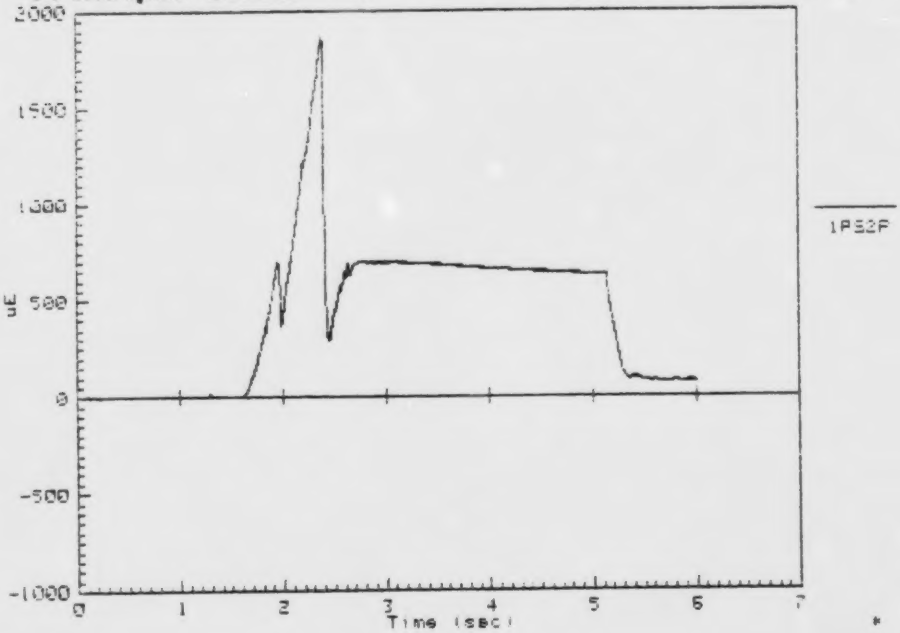
GEOTEChnical Resources Ltd. ANALYSIS DATE:17 May 1988

Blade Surface Pressure **Series PBT Test 9**



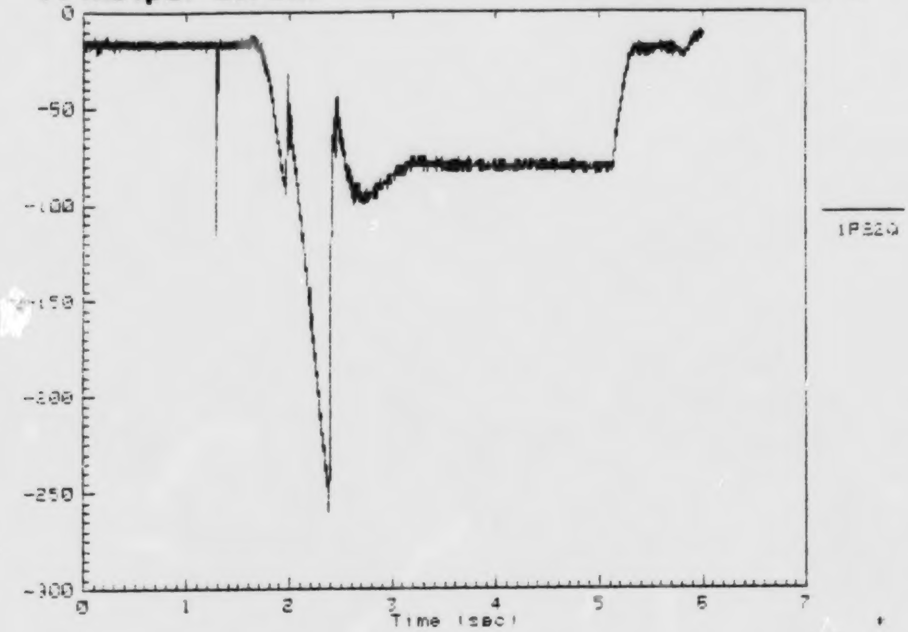
GEOTEChnical Resources Ltd. ANALYSIS DATE:17 May 1988

Principal Strain - P **Series PBT Test 9**



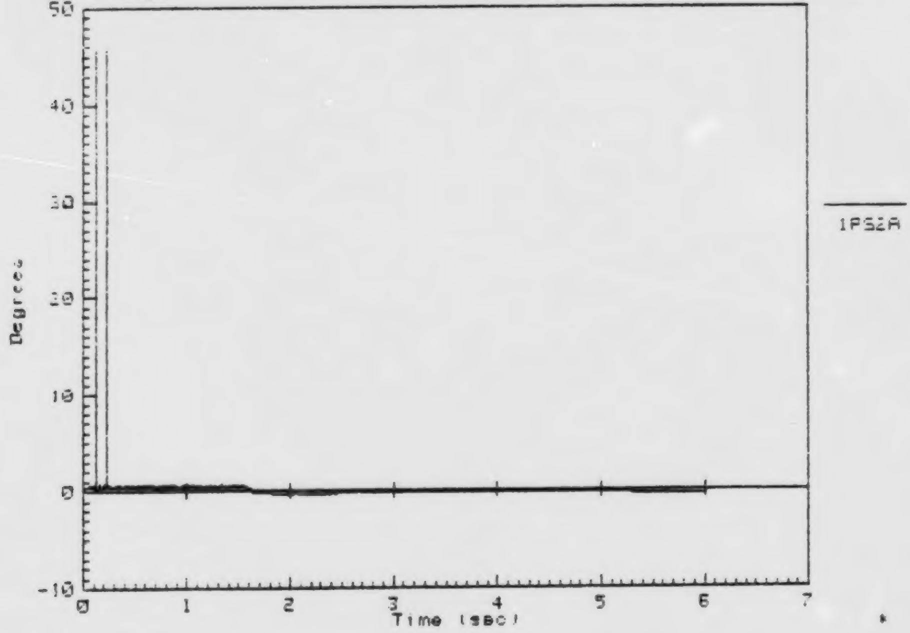
GEOTECHnical Resources Ltd.   ANALYSIS DATE:17 May 1988

Principal Strain - Q   **Series PBT Test 9**



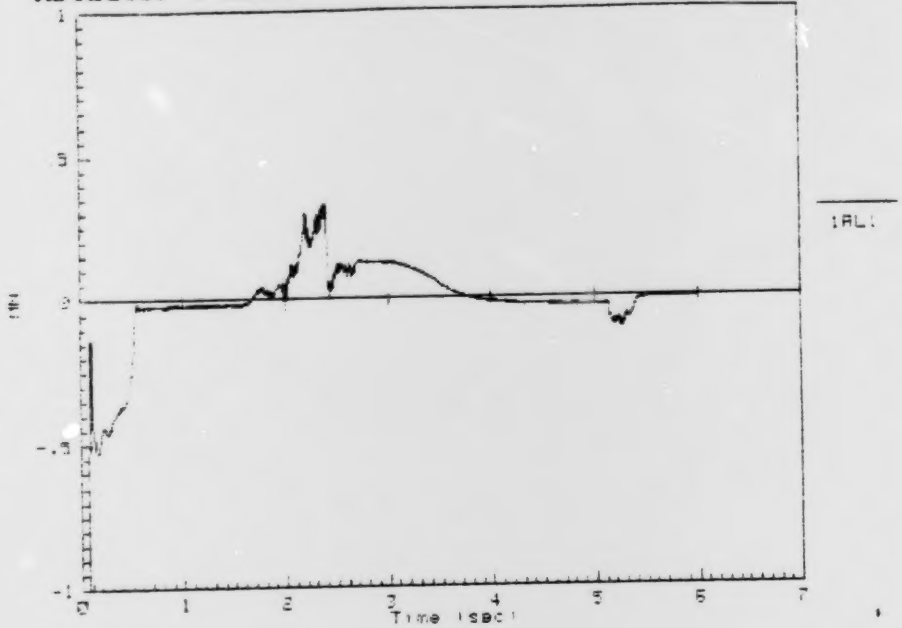
GEOTECHnical Resources Ltd.   ANALYSIS DATE:17 May 1988

Principal strain - Angle   **Series PBT Test 9**



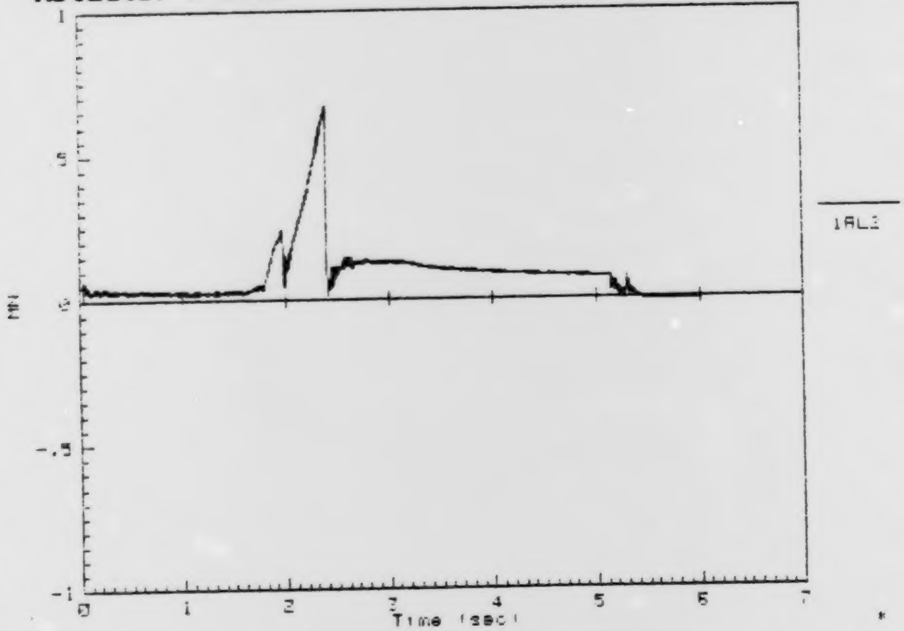
GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

Actuator 1 Load **Series PBT Test 9**



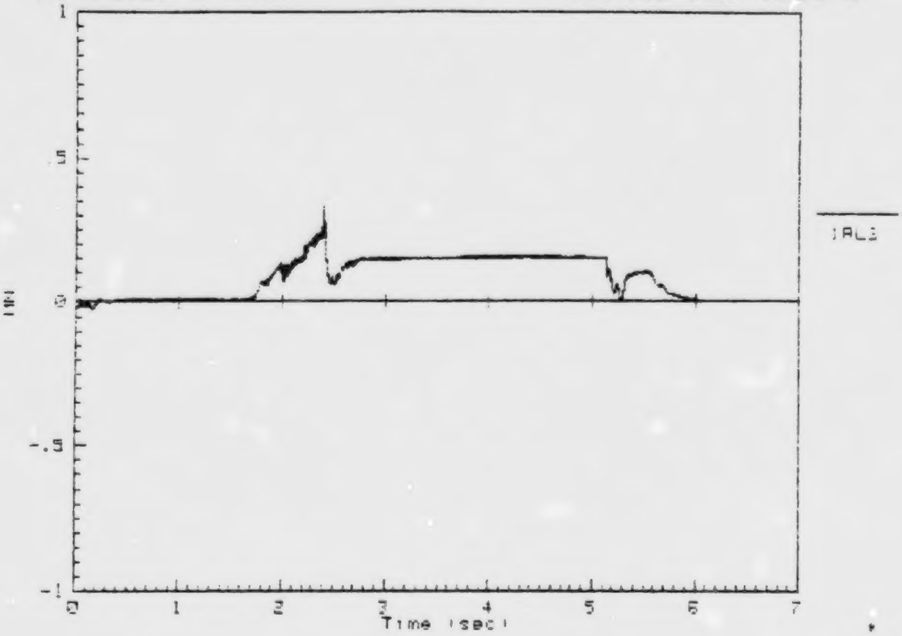
GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

Actuator 2 Load **Series PBT Test 9**



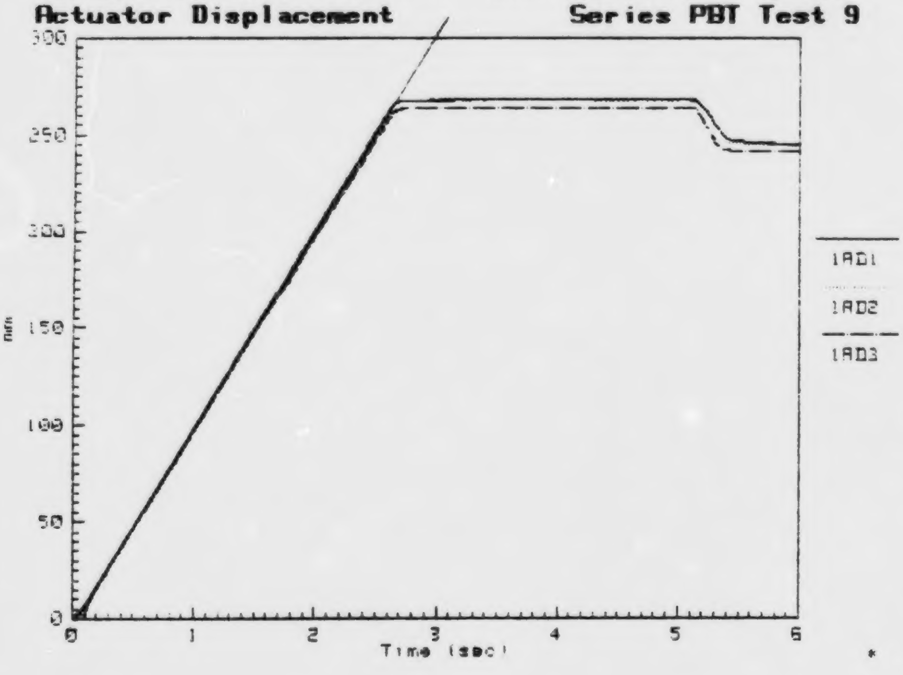
GEOTECHnical Resources Ltd.   ANALYSIS DATE: 17 May 1988

Actuator 3 Load   **Series PBT Test 9**



GEOTECHnical Resources Ltd.   ANALYSIS DATE: 17 May 1988

Actuator Displacement   **Series PBT Test 9**



$v = \frac{300\ mm}{(3 - 0.02\ s)}$

$= 100.7\ \frac{mm}{s}$

GEOTECHnical resources ltd
PROP BUSTERS
PROJECT NUMBER: 9448

```
Date: 17 May 1988
Time: 11:51:03

Test series...... PBT
Test number...... 10

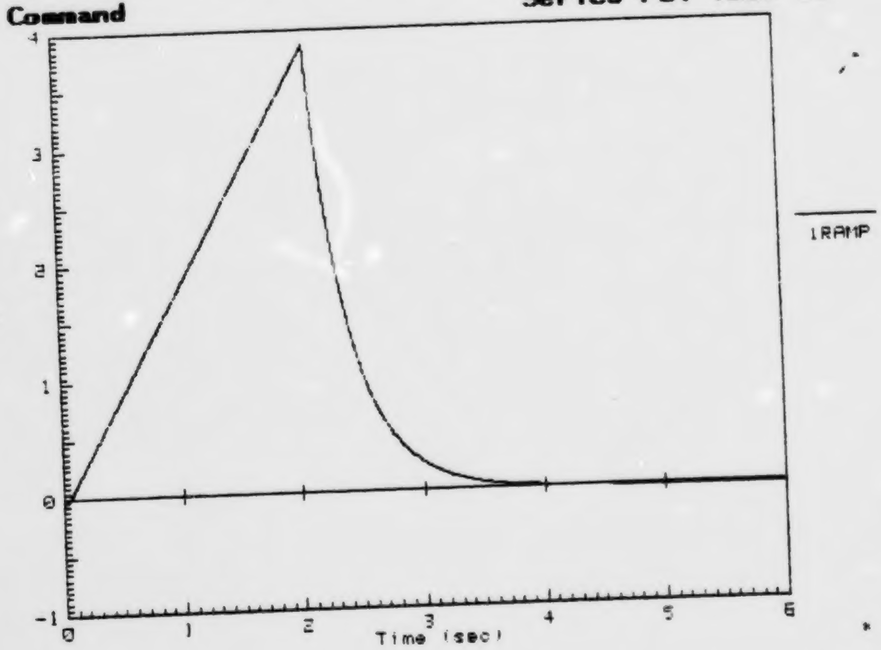
*** Window 1 ***
Test duration .................... 6 Second(s)
AD-200 sample period............. 16.1 Micro-second(s)
Sample rate, aggregate .......... 62111 Hz.
Sample rate per channel ......... 3881 Hz.
Number of samples per channel .. 23292 words.
Total number of samples ........ 745344 words.
Trigger source ................... INTERNAL
Number of cards .................. 2
Number of channels per card .... 16
Total number of channels ....... 32
```

Transducer table for test #PBT10_HDR

```
14750 Card1:!
14760    |-----|--|--|--|--|----|--------|--------|-------|------|---------|
14770    |Card |Ch|SW|HW|Ex|Mode| Gain   : Offset : Units :  Ch  : Serial  :
14780    | no. |no|gn|gn|gn|    | (eng/V)|  (V)   : (/V)  :  Id  : Number  :
14790    |-----|--|--|--|--|----|--------|--------|-------|------|---------|
14800    DATA 1, 1, 1, 1, 1, "S",  107.29,  2.7124,   "mm", "BD1",  "A33380"
14810    DATA 1, 2, 1, 1, 1, "S",  107.42,  2.0726,   "mm", "BD2",  "A22090"
14820    DATA 1, 3, 1, 1, 1, "S",  107.42,  2.3608,   "mm", "BD3",  "A22091"
14830    DATA 1, 4, 1, 1, 1, "S",  6.8529,  0.0879,  "MPa","APR1",    "5817"
14840    DATA 1, 5, 1, 1, 1, "S",  6.8586,  0.0049,  "MPa","APE1",    "4936"
14850    DATA 1, 6, 1, 1, 1, "S",  6.8792,  0.0562,  "MPa","APR2",    "5723"
14860    DATA 1, 7, 1, 1, 1, "S",  6.3636,  0.0708,  "MPa","APE2",    "5815"
14870    DATA 1, 8, 1, 1, 1, "S",  6.5643,  0.0806,  "MPa","APR3",    "5883"
14880    DATA 1, 9, 1, 1, 1, "S",  6.8531,  0.0562,  "MPa","APE3",    "5885"
14890    DATA 1,10, 1, 1, 1, "S",  13.709,  0.0757,  "MPa", "BP1",    "5887"
14900    DATA 1,11, 1, 1, 1, "S",  13.712,  0.1025,  "MPa", "BP2",    "5773"
14910    DATA 1,12, 1, 1, 1, "S",  13.734,  0.0806,  "MPa", "BP3",    "5892"
14920    DATA 1,13, 1, 1, 1, "S",  13.731,  0.0708,  "MPa", "BP4",    "5889"
14930    DATA 1,14, 1, 1, 1, "S",  13.717,  0.0635,  "MPa", "BP5",    "5891"
14940    DATA 1,15, 1, 1, 2, "S",     1.0,       0,  "  V","RAMP",  "      "
14950    DATA 1,16, 1, 1, 1, "S",  1000.0,       0,   "uE","BR1B",  "      "
14960 Card2:!
14970    DATA 2, 1 ,1, 1, 2, "S",  53.306,  1.3525,   "mm", "AD1",  "A22091"
14980    DATA 2, 2, 1, 1, 2, "S",  53.634,  1.3379,   "mm", "AD2",  "A33381"
14990    DATA 2, 3, 1, 1, 2, "S",  53.608,  1.4599,   "mm", "AD3",  "A33382"
15000    DATA 2, 4, 1, 1, 1, "S",  1000.0,       0,   "uE","BR1A",  "      "
15010    DATA 2, 5, 1, 1, 1, "S",  1000.0,       0,   "uE","BR2A",  "      "
15020    DATA 2, 6, 1, 1, 1, "S",  1000.0,       0,   "uE","FSG3",  "      "
15030    DATA 2, 7, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS7",  "      "
15040    DATA 2, 8, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS8",  "      "
15050    DATA 2, 9, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS9",  "      "
15060    DATA 2,10, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS1",  "      "
15070    DATA 2,11, 1, 1, 1, "S",  1000.0,       0,   "uE","BR2B",  "      "
15080    DATA 2,12, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS3",  "      "
15090    DATA 2,13, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS4",  "      "
15100    DATA 2,14, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS2",  "      "
15110    DATA 2,15, 1, 1, 1, "S",  1000.0,       0,   "uE","BR2C",  "      "
15120    DATA 2,16, 1, 1, 1, "S",  1000.0,       0,   "uE","BR1C",  "      "
15130    |-----|--|--|--|--|----|--------|--------|-------|------|---------|
15140    |Card |Ch|SW|HW|Ex|Mode| Gain   | Offset | Units |  Ch  | Serial  |
15150    | no. |no|gn|gn|gn|    | (Eng/V)|  (V)   | (/V)  |  Id  | Number  |
15160    |-----|--|--|--|--|----|--------|--------|-------|------|---------|
15170 End_transducers:!
```

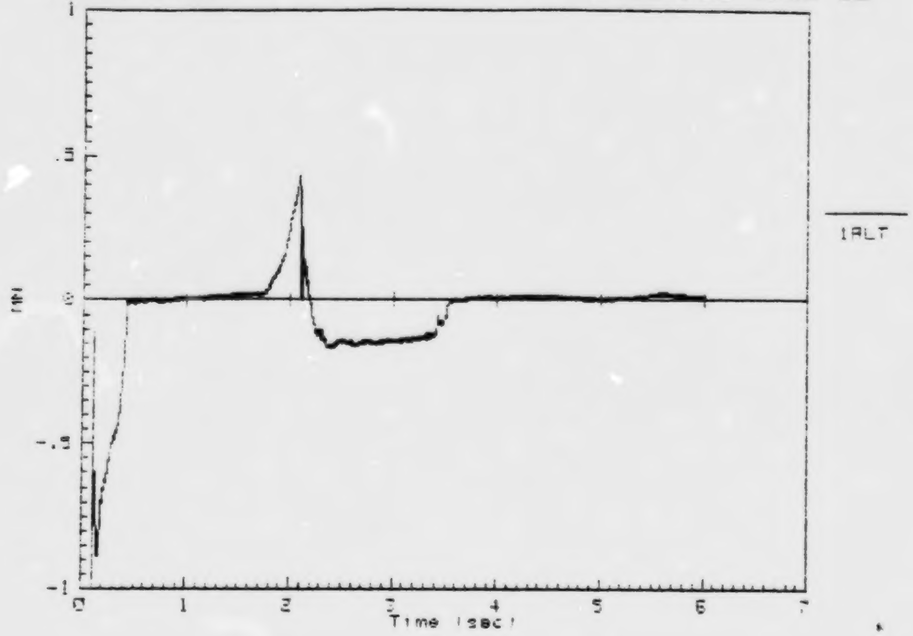
GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

Series PBT Test 10



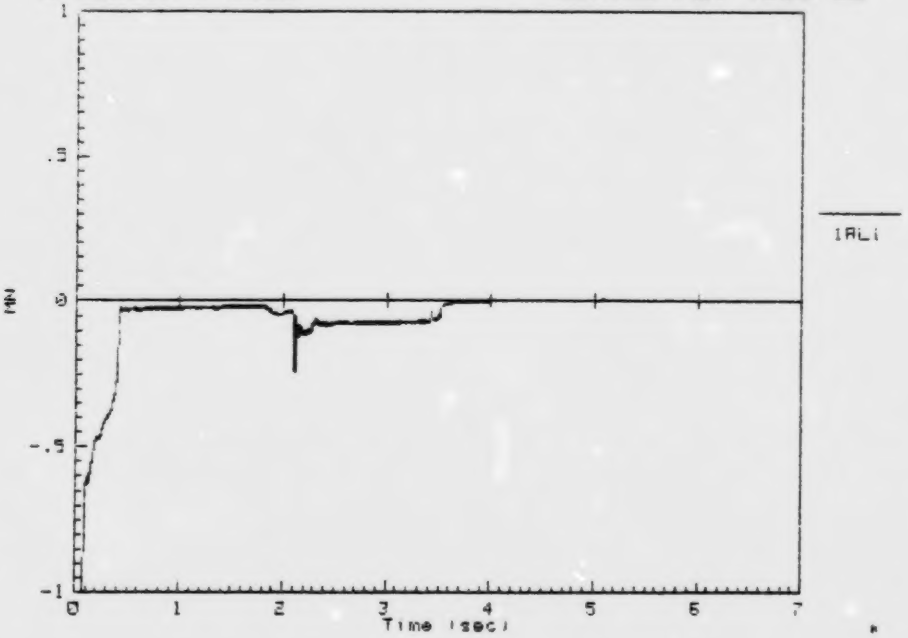
GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

Total Load **Series PBT Test 10**



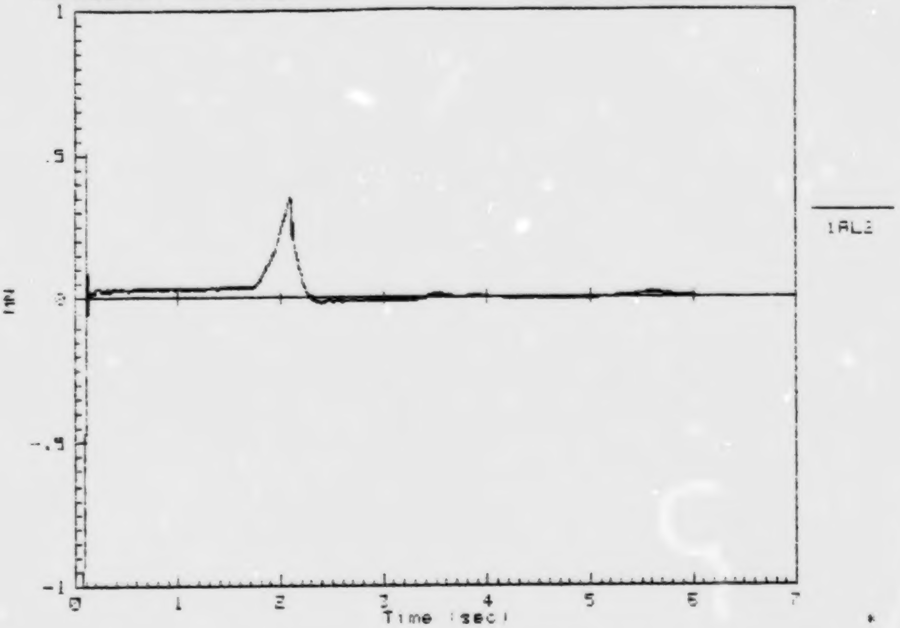
GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

Actuator 1 Load **Series PBT Test 10**



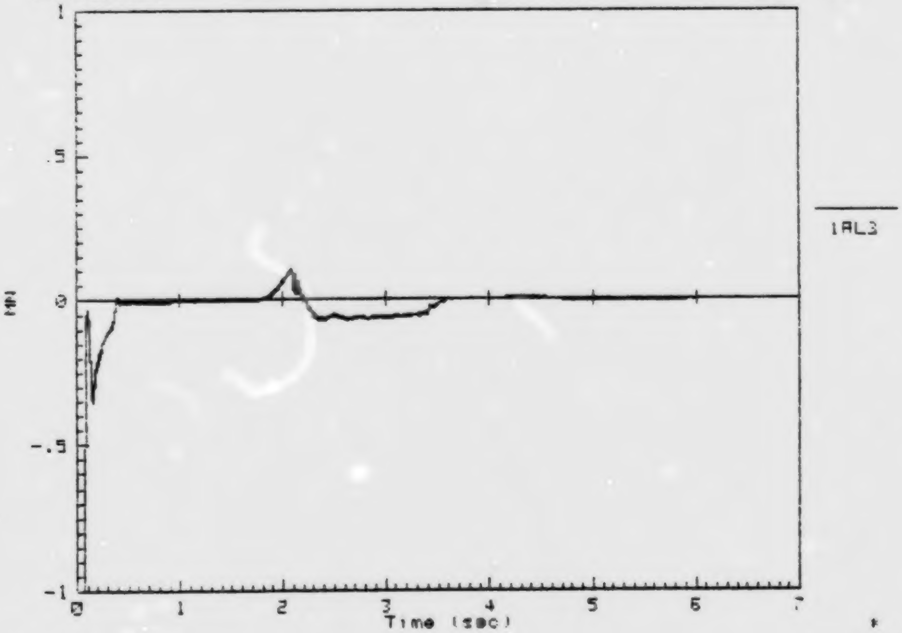
GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

Actuator 2 Load **Series PBT Test 10**



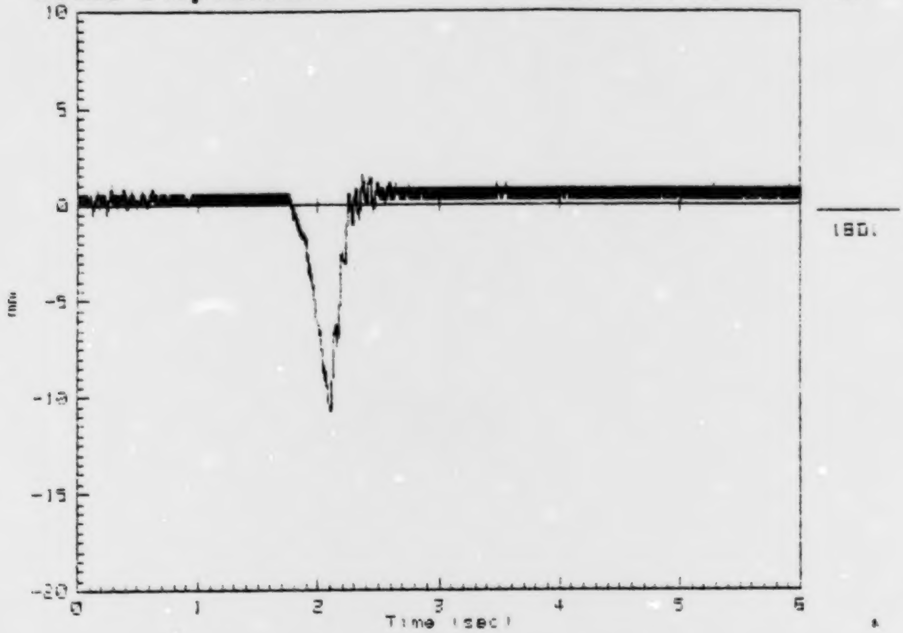
GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

Actuator 3 Load **Series PBT Test 10**



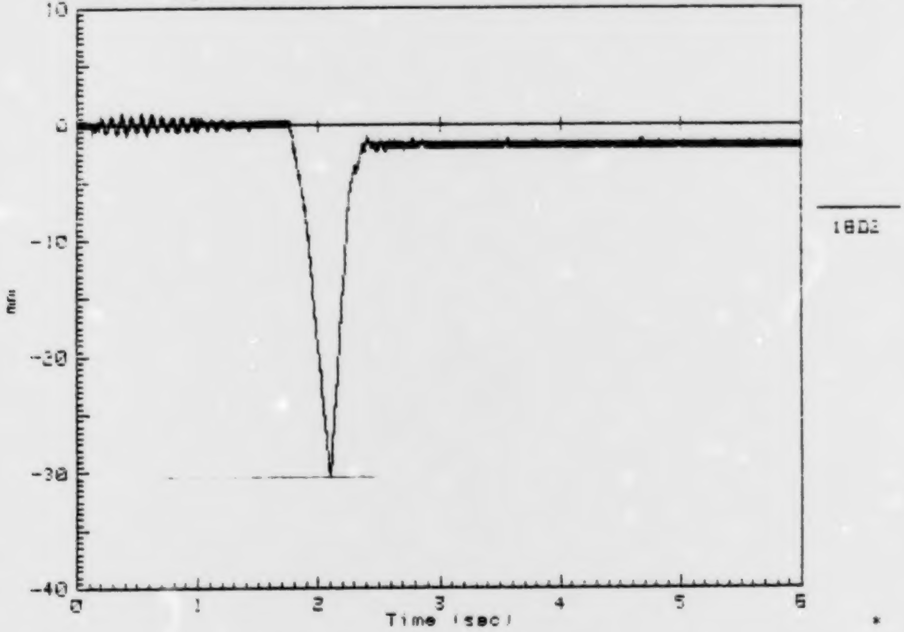
GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

Blade Displacement **Series PBT Test 10**



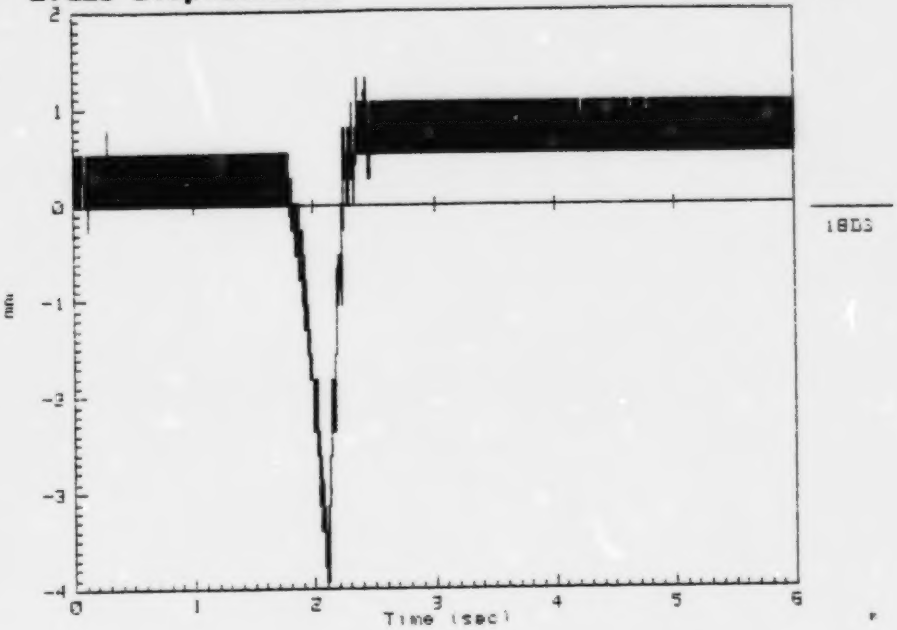
GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

Blade Displacement **Series PBT Test 10**



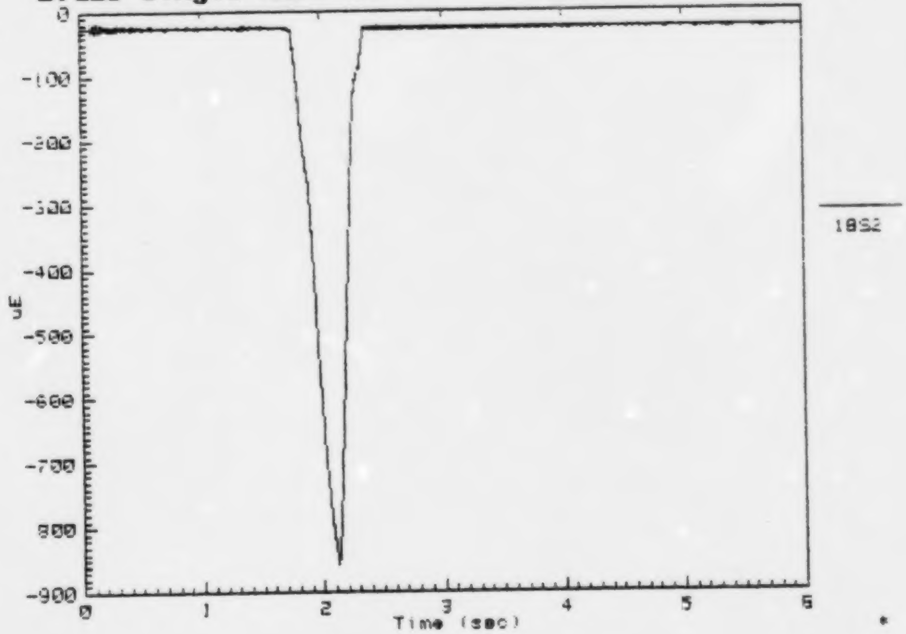
GEOTECHnical Resources Ltd. ANALYSIS DATE: 17 May 1988

Blade Displacement **Series PBT Test 10**



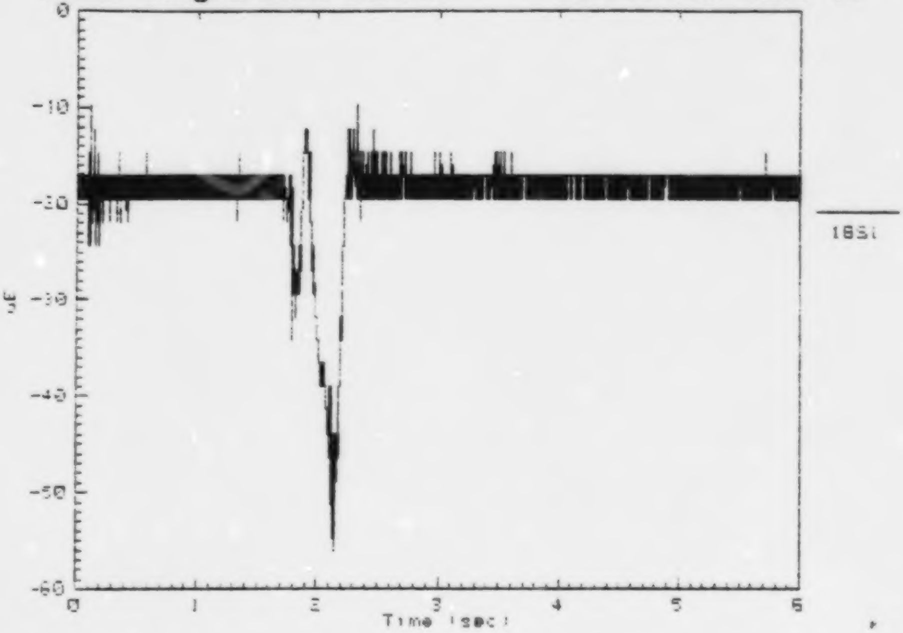
GEOTECHnical Resources Ltd. ANALYSIS DATE: 17 May 1988

Blade Single-Axis Strain **Series PBT Test 10**



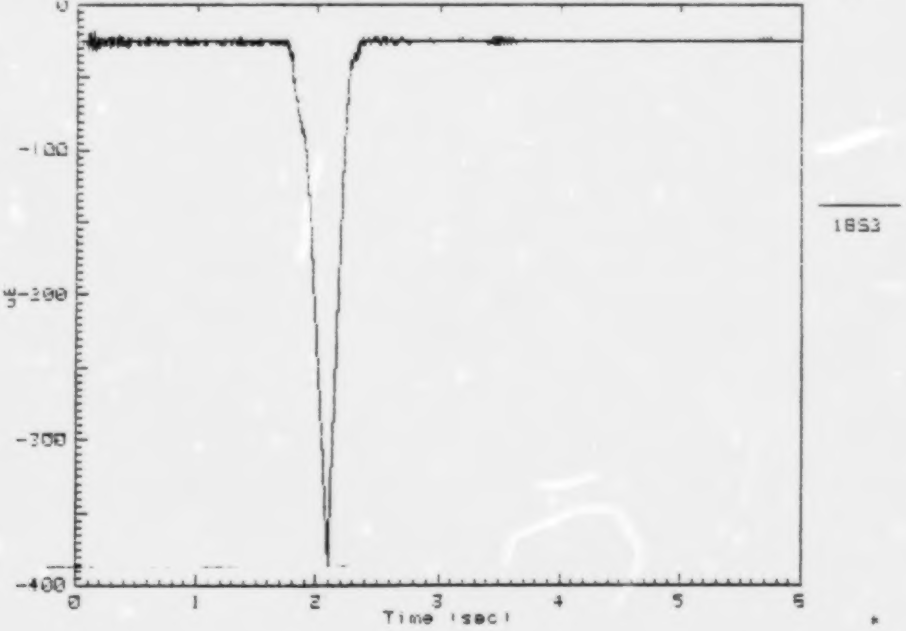
GEOTECHnical Resources Ltd.   ANALYSIS DATE: 17 May 1988

Blade Single-Axis Strain   Series PBT Test 10



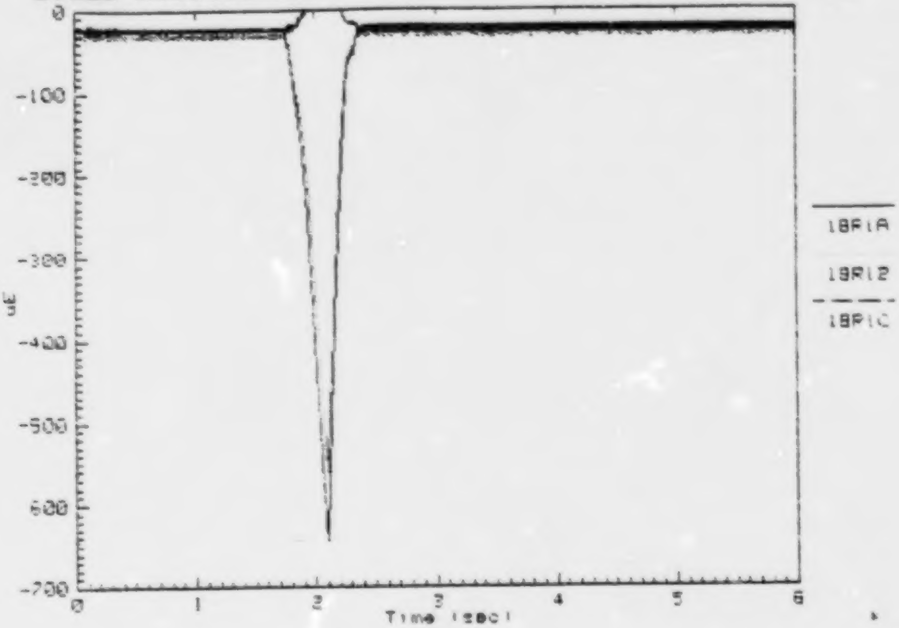
GEOTECHnical Resources Ltd.   ANALYSIS DATE: 17 May 1988

Blade Single-Axis Strain   Series PBT Test 10



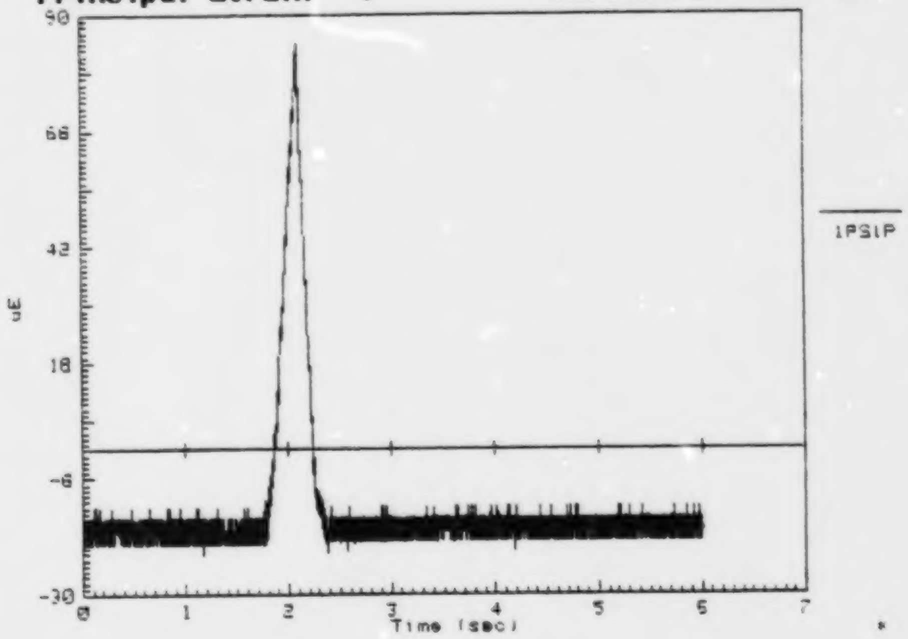
GEOTECHnical Resources Ltd. ANALYSIS DATE: 17 May 1988

Blade Rosette Strain **Series PBT Test 10**



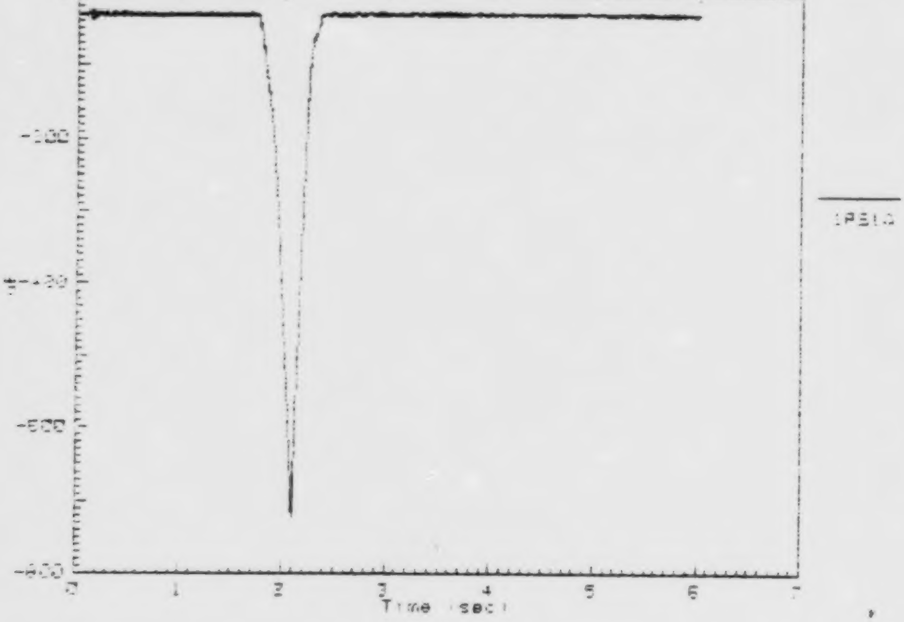
GEOTECHnical Resources Ltd. ANALYSIS DATE: 17 May 1988

Principal Strain - P **Series PBT Test 10**



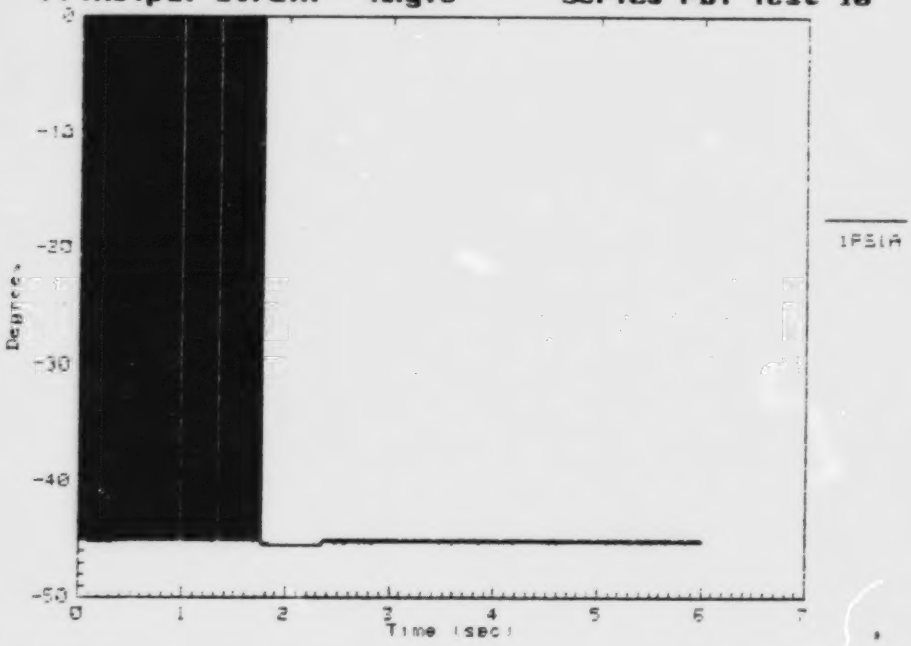
GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

Principal Strain - Q **Series PBT Test 10**



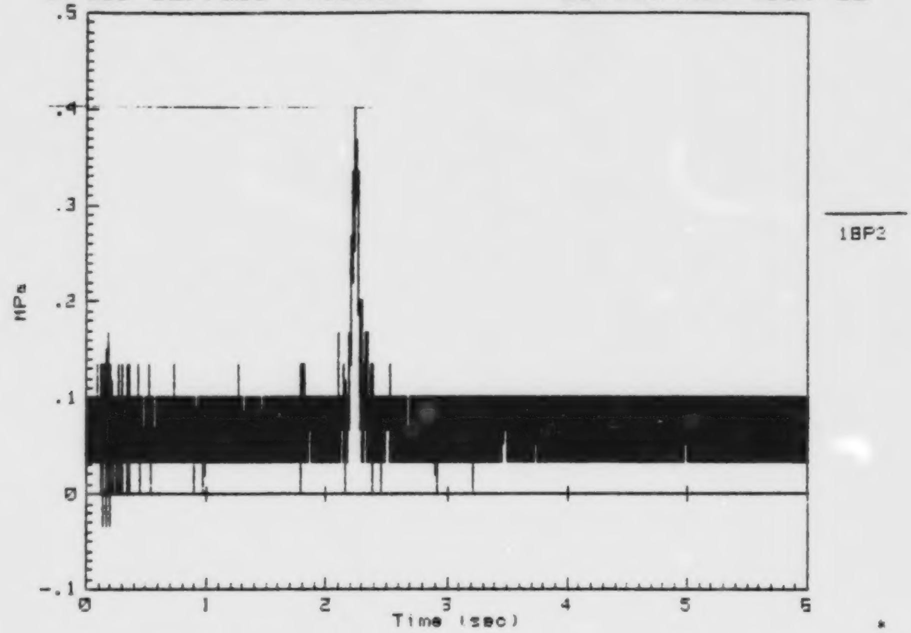
GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

Principal strain - Angle **Series PBT Test 10**



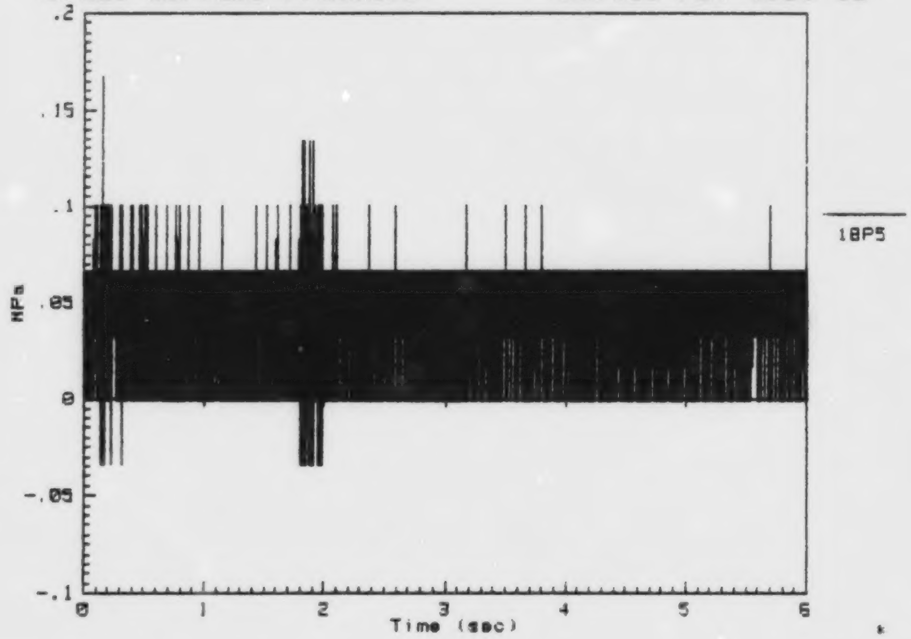
GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

Blade Surface Pressure Series PBT Test 10



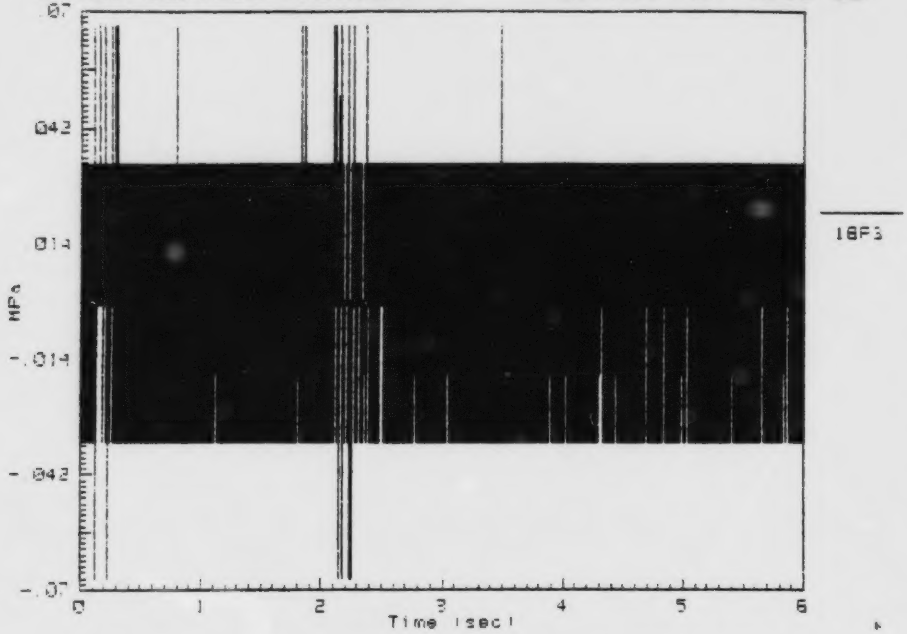
GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

Blade Surface Pressure Series PBT Test 10



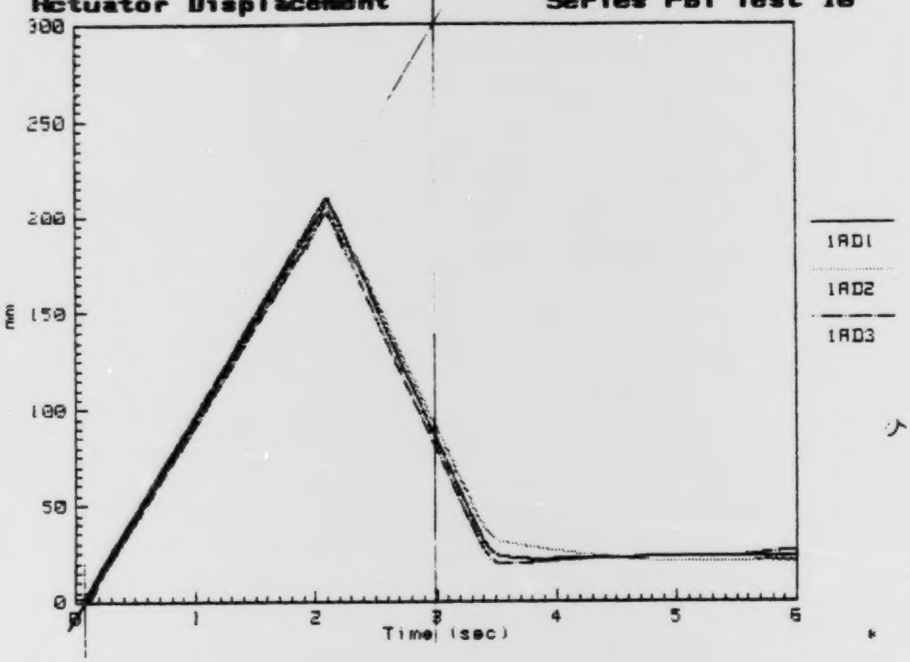
GEOTECHnical Resources Ltd.   ANALYSIS DATE:17 May 1988

Blade Surface Pressure   Series PBT Test 10



GEOTECHnical Resources Ltd. ANALYSIS DATE: 12 Jul 1988

Actuator Displacement **Series PBT Test 10**



$$v = \frac{300\ mm}{(3-0.08)\ s}$$

$$= 102.7\ mm/s$$

GEOTECHnical resources ltd
PROP BUSTERS
PROJECT NUMBER: 9448

```
Date: 17 May 1993
Time: 15:15:36

Test series...... PBT
Test number...... 11

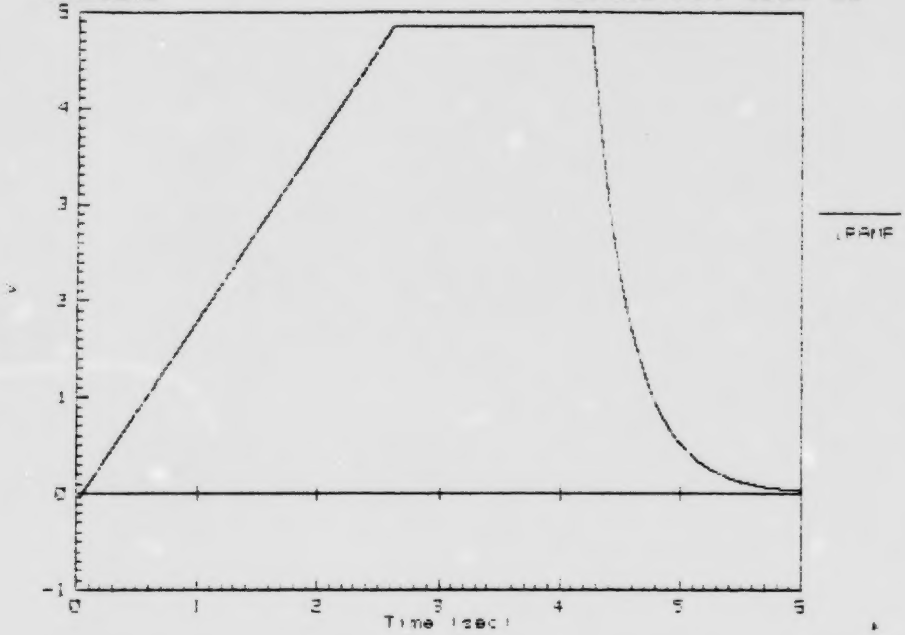
*** Window 1 ***
Test duration ................... 6 Second(s)
AD-200 sample period............. 16.1 Micro-second(s)
Sample rate, aggregate .......... 62111 Hz.
Sample rate per channel ......... 3881 Hz.
Number of samples per channel .. 23292 words.
Total number of samples ........ 745344 words.
Trigger source ................. INTERNAL
Number of cards ................ 2
Number of channels per card .... 16
Total number of channels ....... 32
```

```
Transducer table for test #PBT11_HDR

14750 Card1:!
14760   ¦-----¦--¦--¦--¦--¦----¦--------¦---------¦-------¦------¦---------¦
14770   ¦Card ¦Ch¦SW¦HW¦Ex¦Mode¦  Gain  ¦ Offset  ¦ Units ¦  Ch  ¦  Serial ¦
14780   ¦ no. ¦no¦gn¦gn¦gn¦    ¦(eng/V)¦   (V)   ¦ (/V)  ¦  Id  ¦  Number ¦
14790   ¦-----¦--¦--¦--¦--¦----¦--------¦---------¦-------¦------¦---------¦
14800   DATA 1, 1, 1, 1, 1, "S", 107.29, 2.7124,   "mm", "BD1",  "A33380"
14810   DATA 1, 2, 1, 1, 1, "S", 107.42, 2.0726,   "mm", "BD2",  "A22090"
14820   DATA 1, 3, 1, 1, 1, "S", 107.42, 2.3608,   "mm", "BD3",  "A22091"
14830   DATA 1, 4, 1, 1, 1, "S", 6.8529, 0.0879,  "MPa","APR1",    "5817"
14840   DATA 1, 5, 1, 1, 1, "S", 6.8586, 0.0049,  "MPa","APE1",    "4986"
14850   DATA 1, 6, 1, 1, 1, "S", 6.8792, 0.0562,  "MPa","APR2",    "5723"
14860   DATA 1, 7, 1, 1, 1, "S", 6.8636, 0.0708,  "MPa","APE2",    "5815"
14870   DATA 1, 8, 1, 1, 1, "S", 6.8643, 0.0806,  "MPa","APR3",    "5883"
14880   DATA 1, 9, 1, 1, 1, "S", 6.8531, 0.0562,  "MPa","APE3",    "5885"
14890   DATA 1,10, 1, 1, 1, "S", 13.709, 0.0757,  "MPa", "BP1",    "5887"
14900   DATA 1,11, 1, 1, 1, "S", 13.712, 0.1025,  "MPa", "BP2",    "5773"
14910   DATA 1,12, 1, 1, 1, "S", 13.734, 0.0806,  "MPa", "BP3",    "5892"
14920   DATA 1,13, 1, 1, 1, "S", 13.731, 0.0708,  "MPa", "BP4",    "5889"
14930   DATA 1,14, 1, 1, 1, "S", 13.717, 0.0635,  "MPa", "BP5",    "5891"
14940   DATA 1,15, 1, 1, 2, "S",    1.0,      0,  "  V","RAMP",   "    "
14950   DATA 1,16, 1, 1, 1, "S", 1000.0,      0,   "uE","BR1B",   "    "
14960 Card2:!
14970   DATA 2, 1 ,1, 1, 2, "S", 53.906, 1.3525,   "mm", "AD1",  "A22091"
14980   DATA 2, 2, 1, 1, 2, "S", 53.634, 1.3379,   "mm", "AD2",  "A33381"
14990   DATA 2, 3, 1, 1, 2, "S", 53.608, 1.4599,   "mm", "AD3",  "A33382"
15000   DATA 2, 4, 1, 1, 1, "S", 1000.0,      0,   "uE","BR1A",   "    "
15010   DATA 2, 5, 1, 1, 1, "S", 1000.0,      0,   "uE","BR2A",   "    "
15020   DATA 2, 6, 1, 1, 1, "S", 1000.0,      0,   "uE","FSG3",   "    "
15030   DATA 2, 7, 1, 1, 1, "S", 1000.0,      0,   "uE", "BS7",   "    "
15040   DATA 2, 8, 1, 1, 1, "S", 1000.0,      0,   "uE", "BS8",   "    "
15050   DATA 2, 9, 1, 1, 1, "S", 1000.0,      0,   "uE", "BS9",   "    "
15060   DATA 2,10, 1, 1, 1, "S", 1000.0,      0,   "uE", "BS1",   "    "
15070   DATA 2,11, 1, 1, 1, "S", 1000.0,      0,   "uE","BR2B",   "    "
15080   DATA 2,12, 1, 1, 1, "S", 1000.0,      0,   "uE", "BS3",   "    "
15090   DATA 2,13, 1, 1, 1, "S", 1000.0,      0,   "uE", "BS4",   "    "
15100   DATA 2,14, 1, 1, 1, "S", 1000.0,      0,   "uE", "BS2",   "    "
15110   DATA 2,15, 1, 1, 1, "S", 1000.0,      0,   "uE","BR2C",   "    "
15120   DATA 2,16, 1, 1, 1, "S", 1000.0,      0,   "uE","BR1C",   "    "
15130   ¦-----¦--¦--¦--¦--¦----¦--------¦---------¦-------¦------¦---------¦
15140   ¦Card ¦Ch¦SW¦HW¦Ex¦Mode¦  Gain  ¦ Offset  ¦ Units ¦  Ch  ¦  Serial ¦
15150   ¦ no. ¦no¦gn¦gn¦gn¦    ¦(Eng/V)¦   (V)   ¦ (/V)  ¦  Id  ¦  Number ¦
15160   ¦-----¦--¦--¦--¦--¦----¦--------¦---------¦-------¦------¦---------¦
15170 End_transducers:!
```

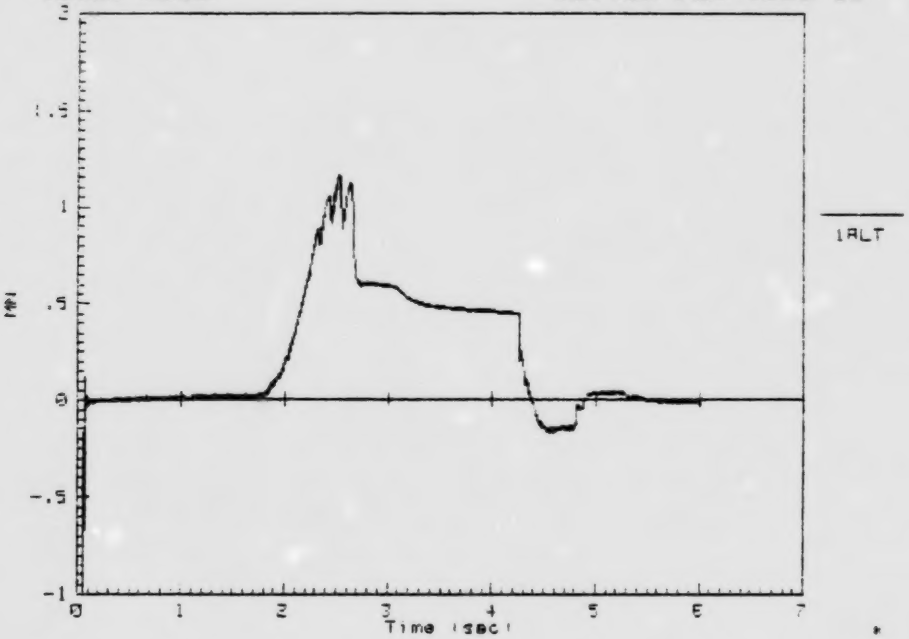
GEOTECHnical Resources Ltd.   ANALYSIS DATE:17 May 1988

Command **Series PBT Test 11**



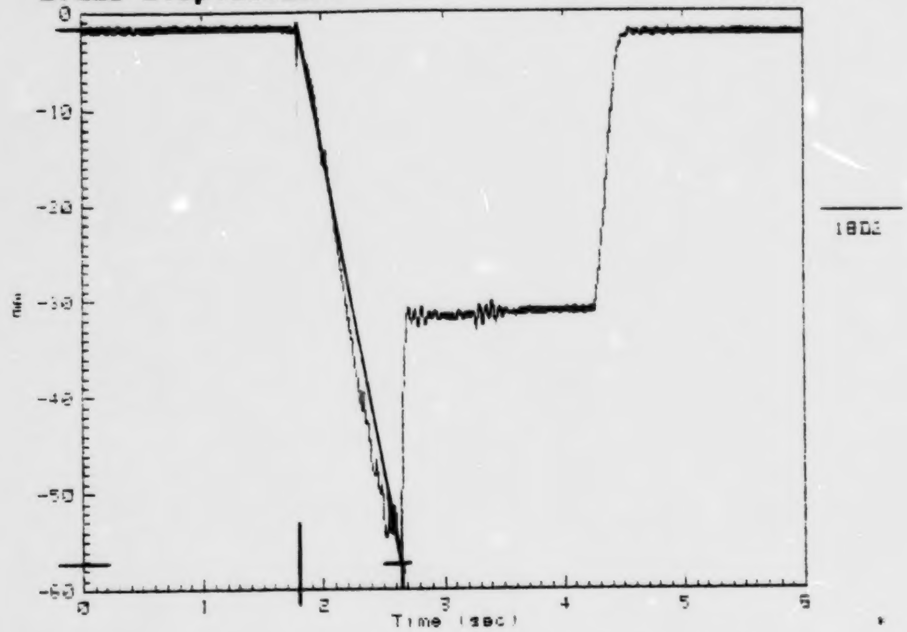
GEOTECHnical Resources Ltd.   ANALYSIS DATE:17 May 1988

Total Load **Series PBT Test 11**



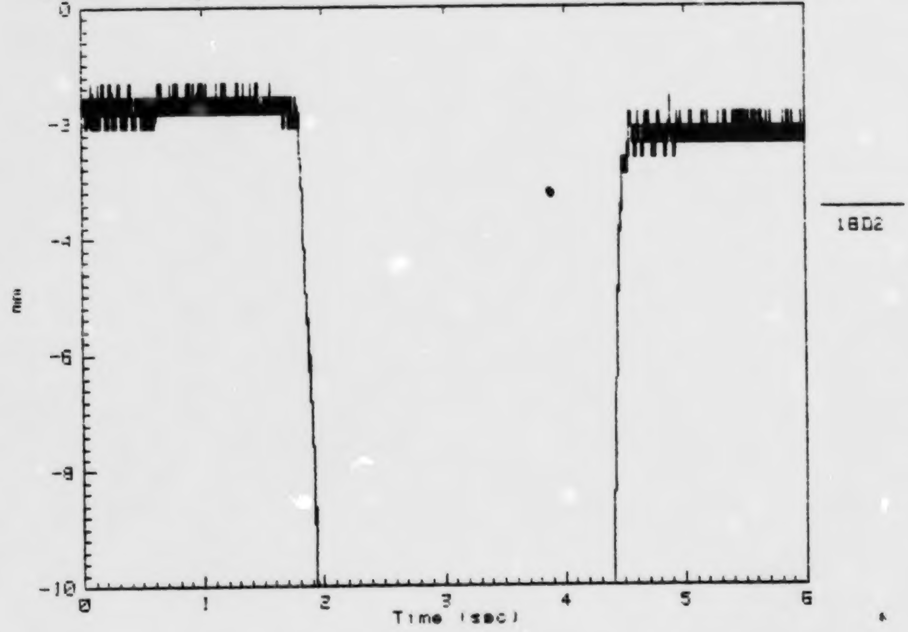
GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

Blade Displacement **Series PBT Test 11**



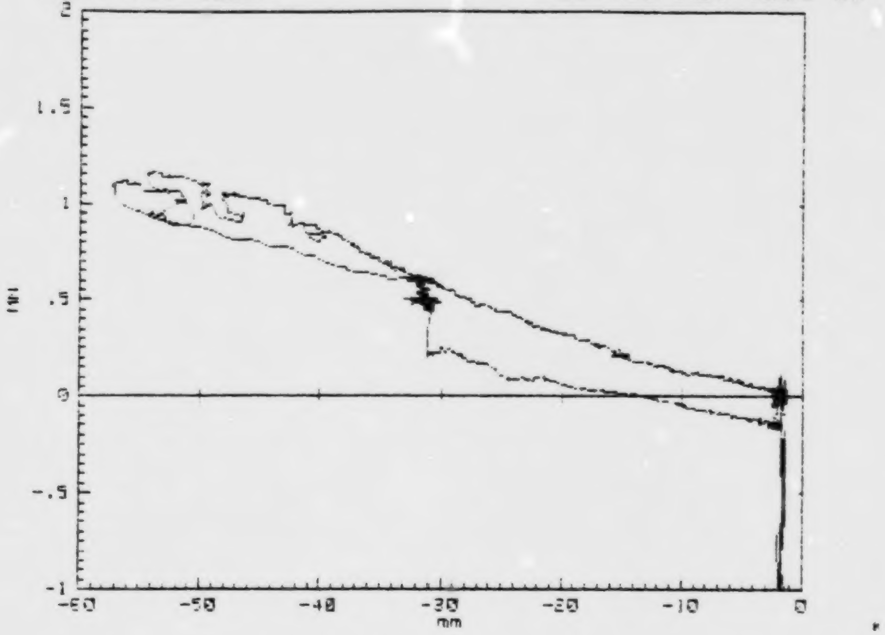
GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

Blade Displacement **Series PBT Test 11**



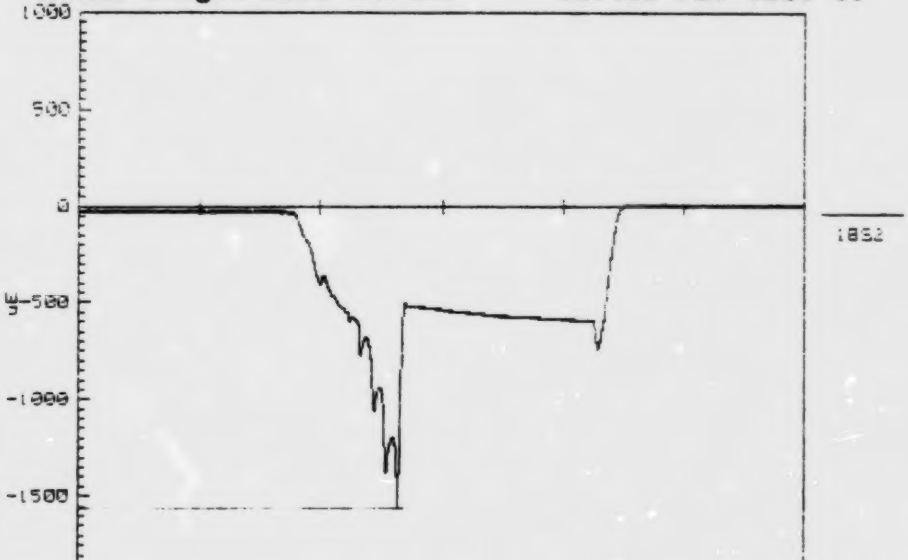
GEOTECHnical Resources Ltd. ANALYSIS DATE: 17 May 1988

1ALT vs. 1BD2 **Series PBT Test 11**



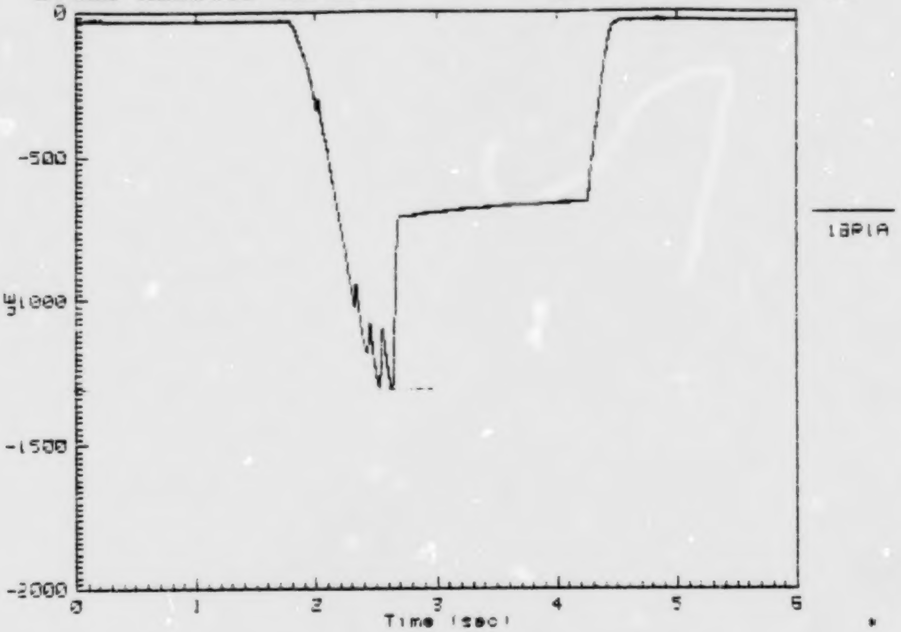
GEOTECHnical Resources Ltd. ANALYSIS DATE: 17 May 1988

Blade Single-Axis Strain **Series PBT Test 11**



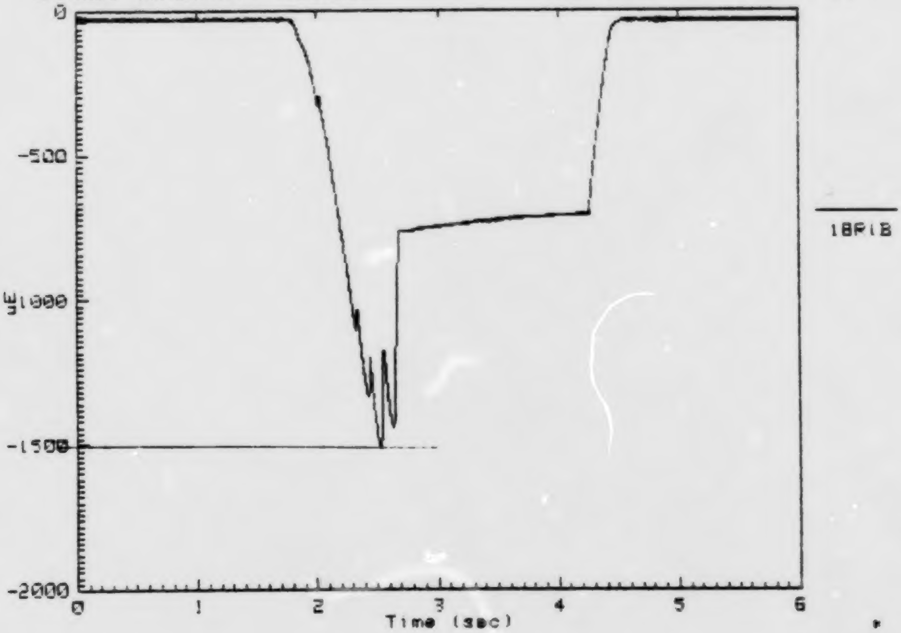
GEOTECHnical Resources Ltd.   ANALYSIS DATE:17 May 1988

Blade Rosette Strain   **Series PBT Test 11**



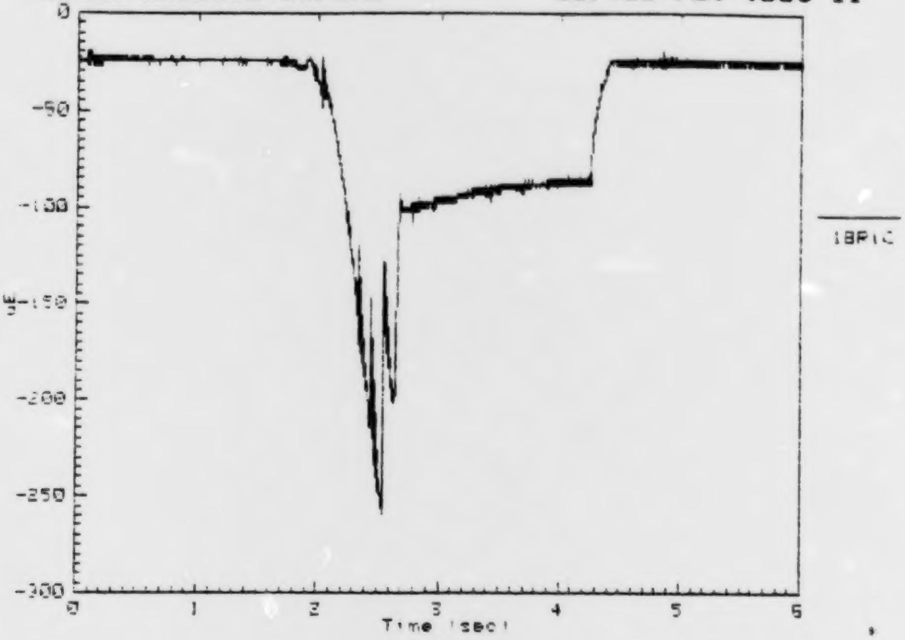
GEOTECHnical Resources Ltd.   ANALYSIS DATE:17 May 1988

Blade Rosette Strain   **Series PBT Test 11**



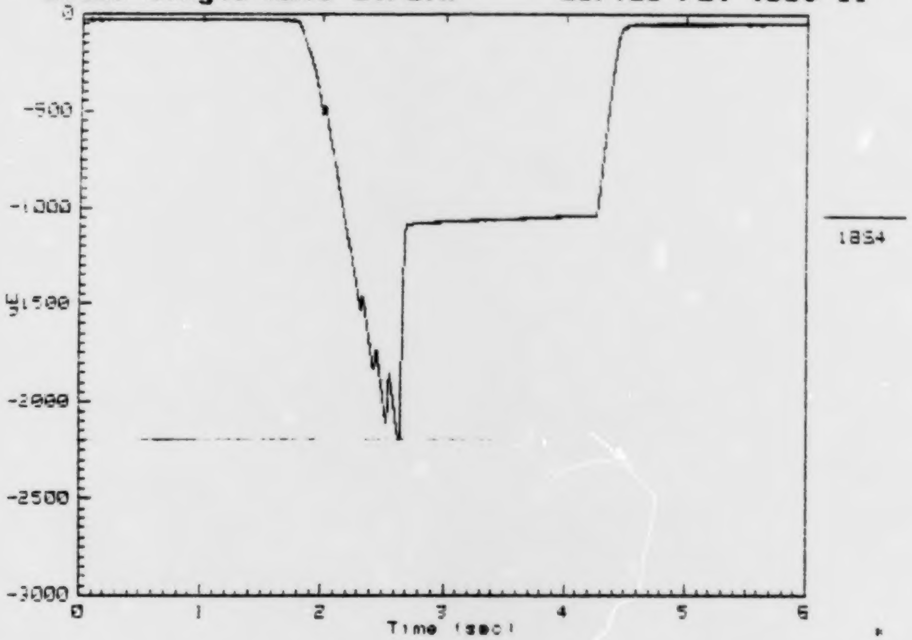
GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

Blade Rosette Strain **Series PBT Test 11**



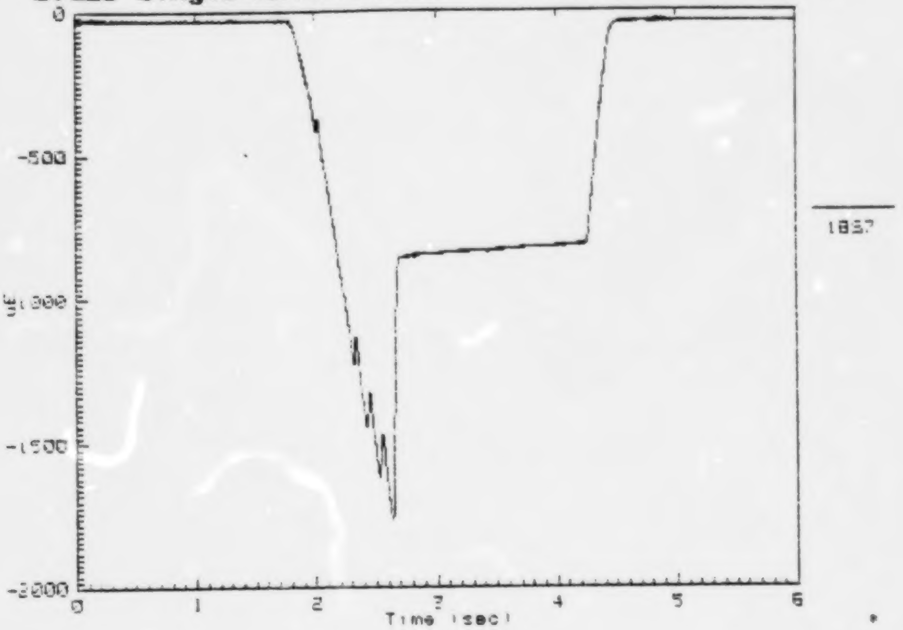
GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

Blade Single-Axis Strain **Series PBT Test 11**



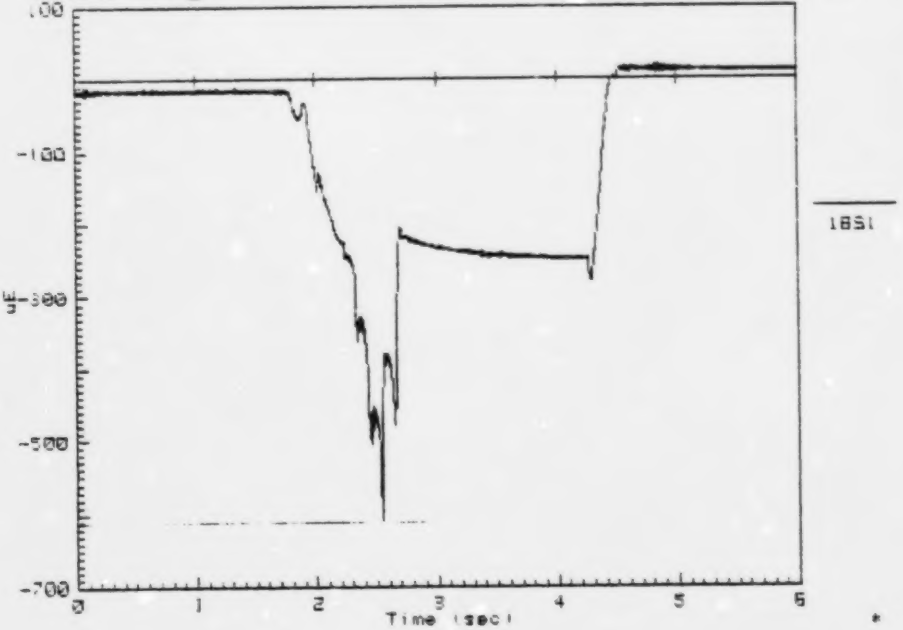
GEOTECHnical Resources Ltd. ANALYSIS DATE: 17 May 1988

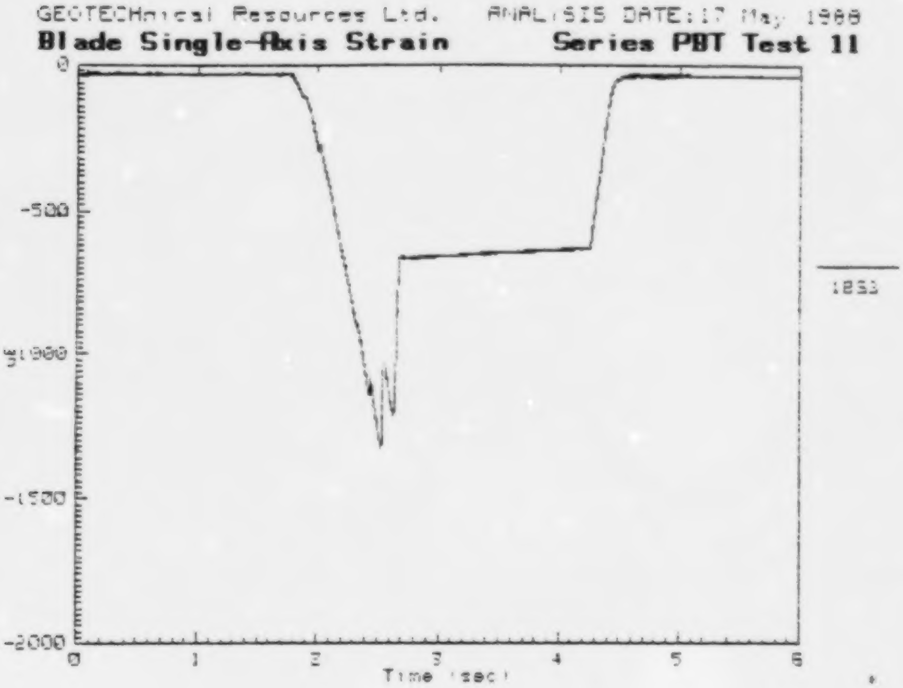
Blade Single-Axis Strain **Series PBT Test 11**

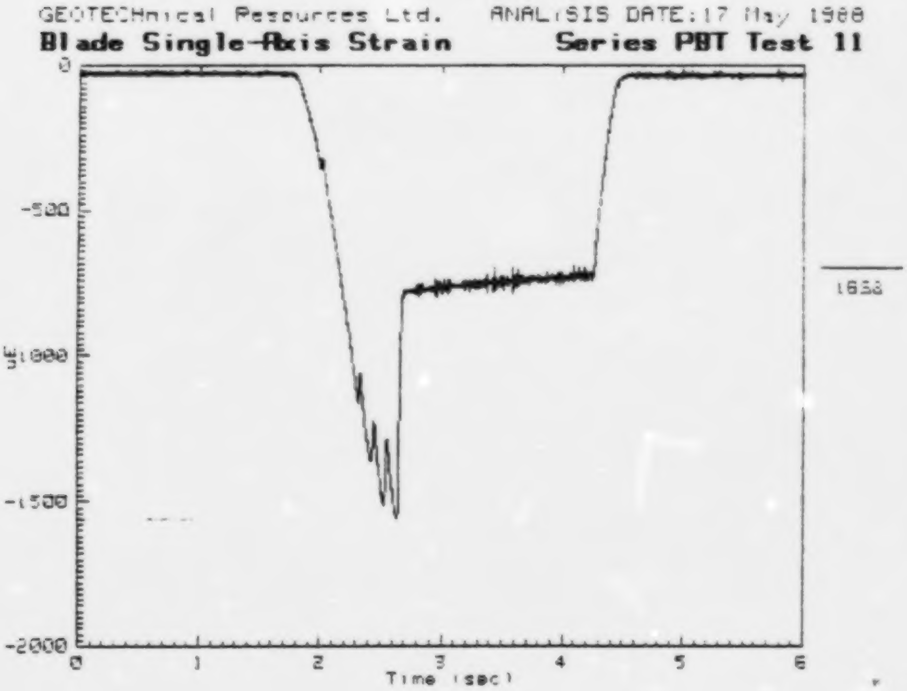


GEOTECHnical Resources Ltd. ANALYSIS DATE: 17 May 1988

Blade Single-Axis Strain **Series PBT Test 11**

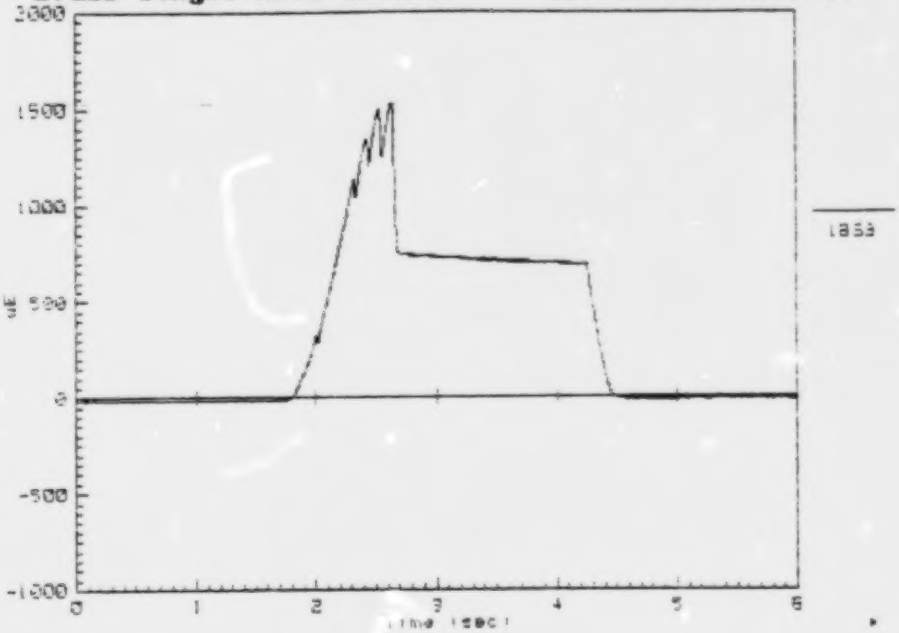



GEOTECHnical Resources Ltd.
ANALYSIS DATE: 17 May 1988
Blade Single-Axis Strain
Series PBT Test 11
0
-500
με
-1000
-1500
-2000
0
1
2
3
4
5
6
Time (sec)
1833


GEOTECHnical Resources Ltd.
ANALYSIS DATE: 17 May 1988
Blade Single-Axis Strain
Series PBT Test 11
0
-500
με
-1000
-1500
-2000
0
1
2
3
4
5
6
Time (sec)
1638

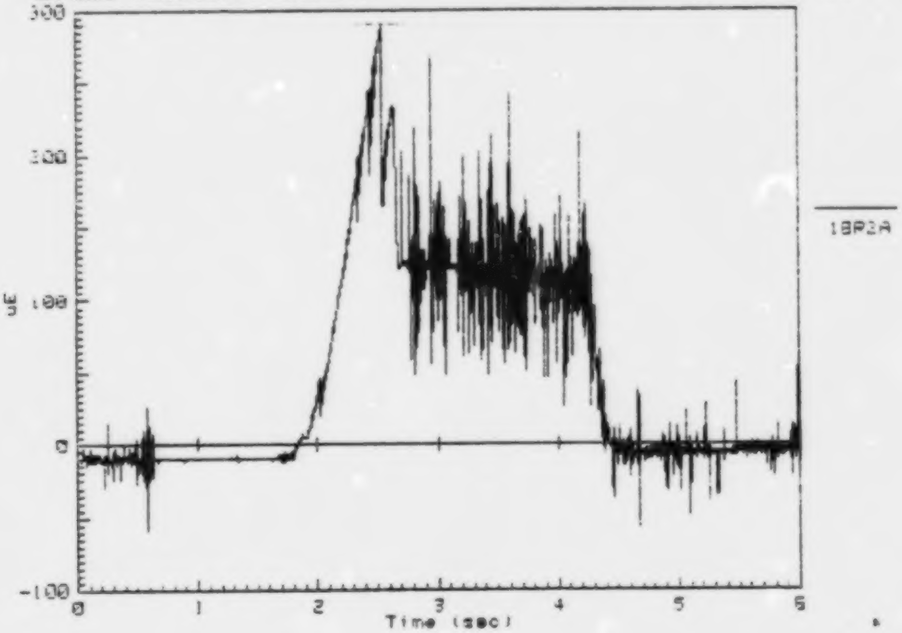
GEOTECHnical Resources Ltd. ANALYSIS DATE: 17 May 1988

Blade Single-Axis Strain **Series PBT Test 11**



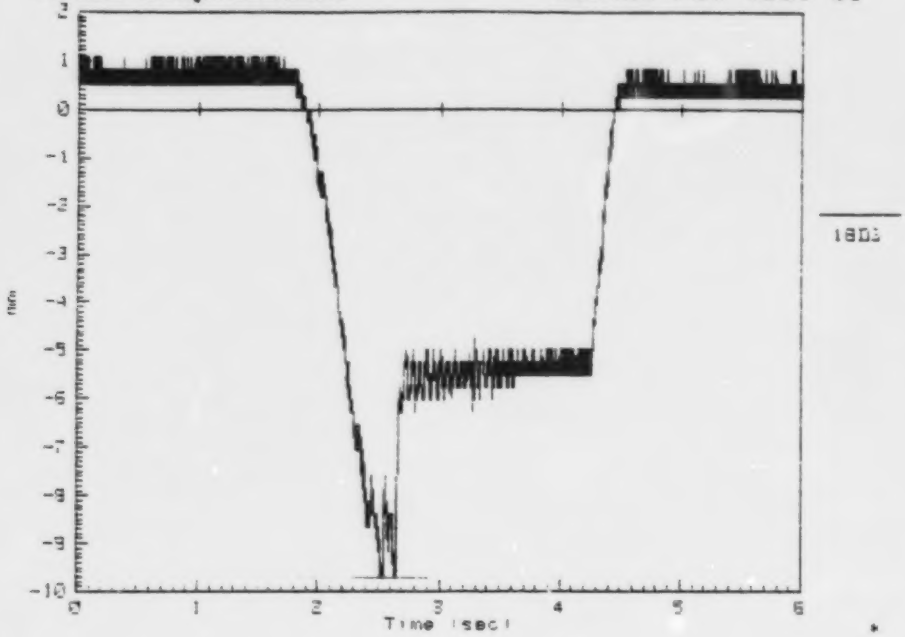
GEOTECHnical Resources Ltd. ANALYSIS DATE: 17 May 1988

Blade Rosette Strain **Series PBT Test 11**



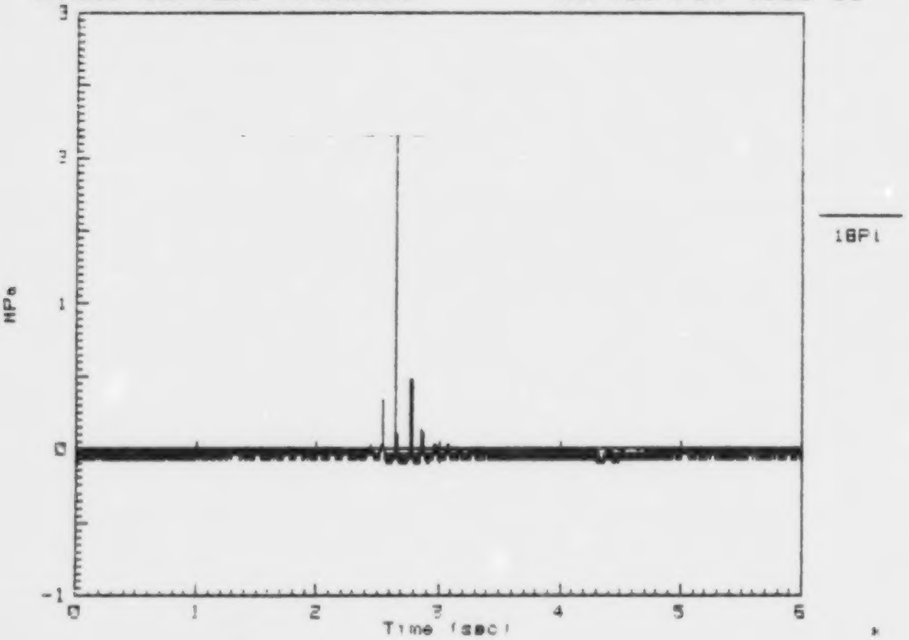
GEOTECHnical Resources Ltd.   ANALYSIS DATE: 17 May 1988

Blade Displacement   Series PBT Test 11



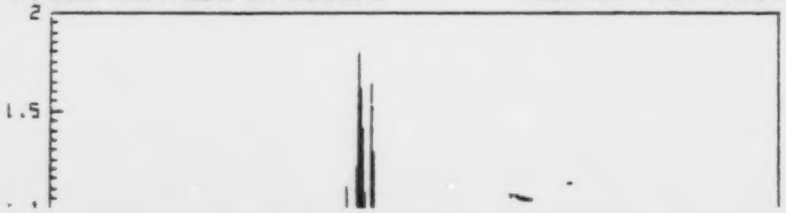
GEOTECHnical Resources Ltd.   ANALYSIS DATE: 17 May 1988

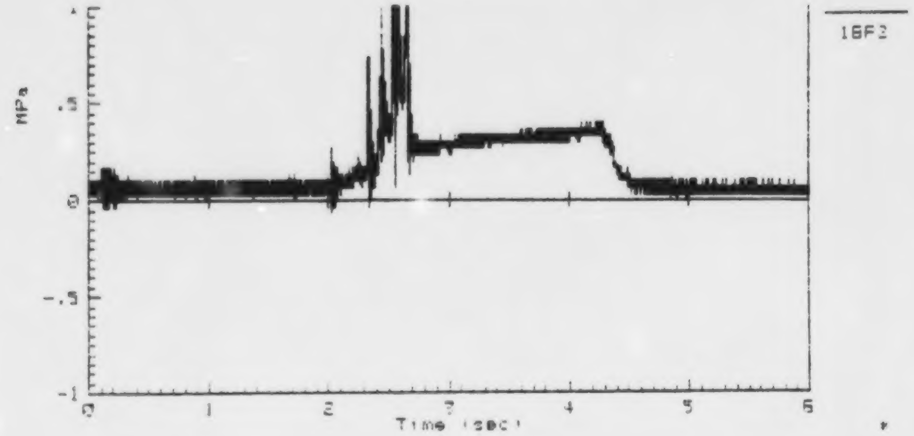
Blade Surface Pressure   Series PBT Test 11



GEOTECHnical Resources Ltd.   ANALYSIS DATE: 17 May 1988

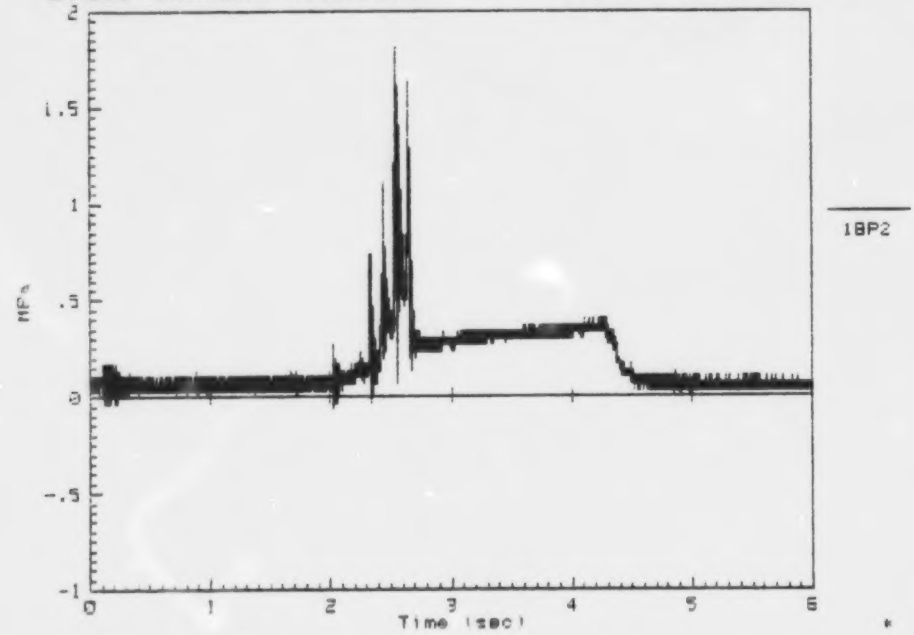
Blade Surface Pressure   Series PBT Test 11





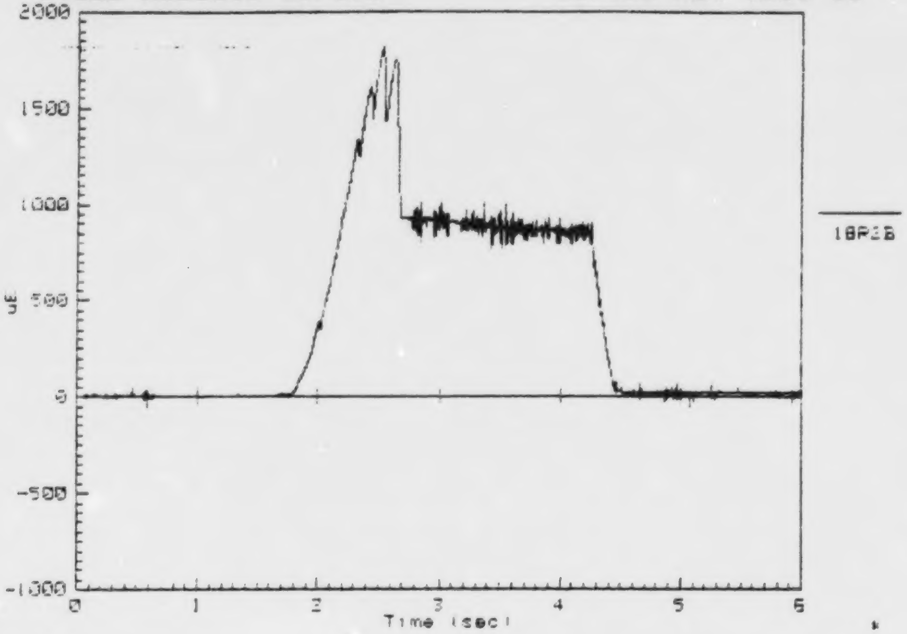
GEOTECHnical Resources Ltd.   ANALYSIS DATE:17 May 1988

Blade Surface Pressure   Series PBT Test 11



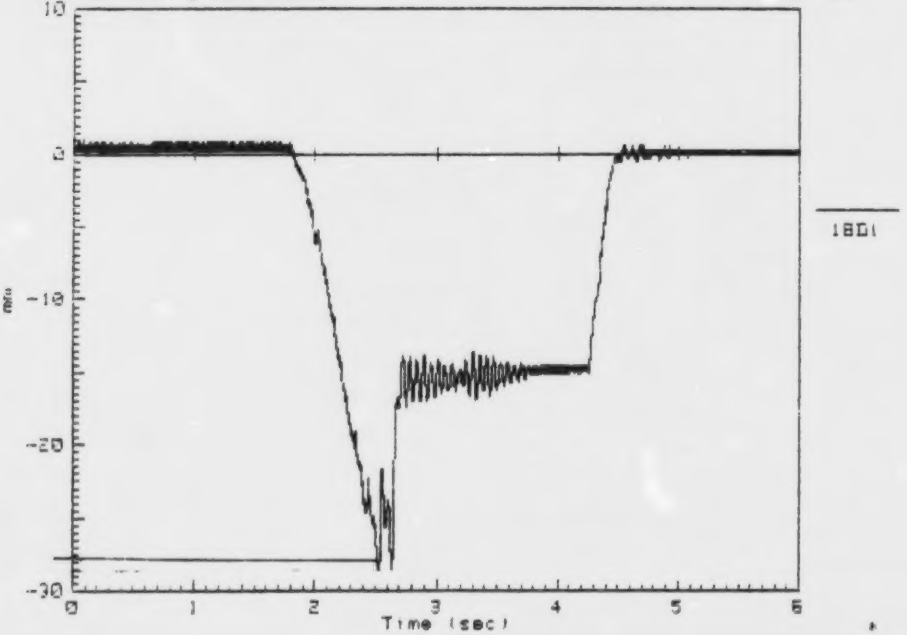
GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

Blade Rosette Strain **Series PBT Test 11**



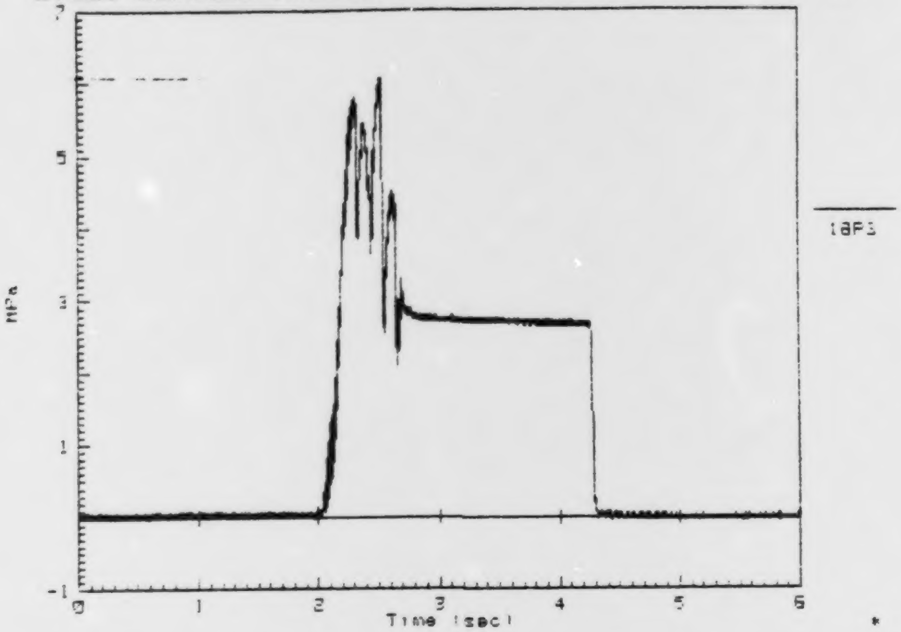
GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

Blade Displacement **Series PBT Test 11**



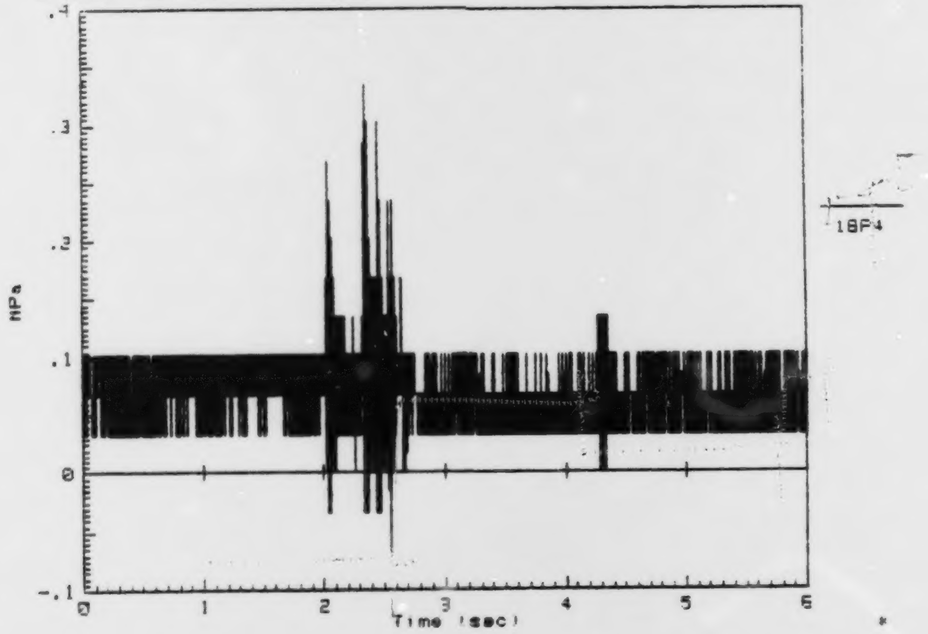
GEOTECHnical Resources Ltd.   ANALYSIS DATE:17 May 1988

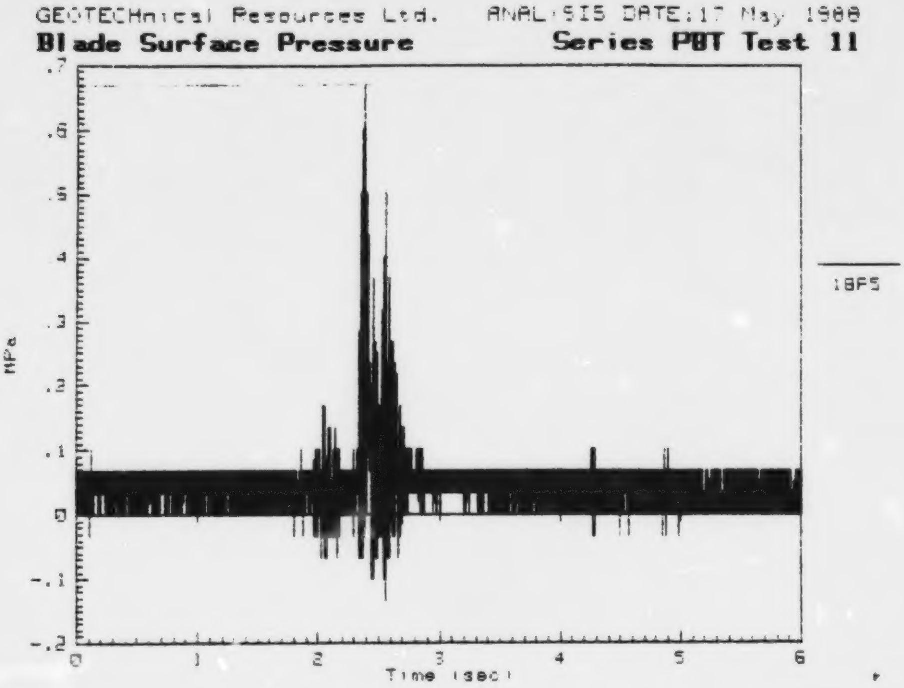
Blade Surface Pressure   **Series PBT Test 11**

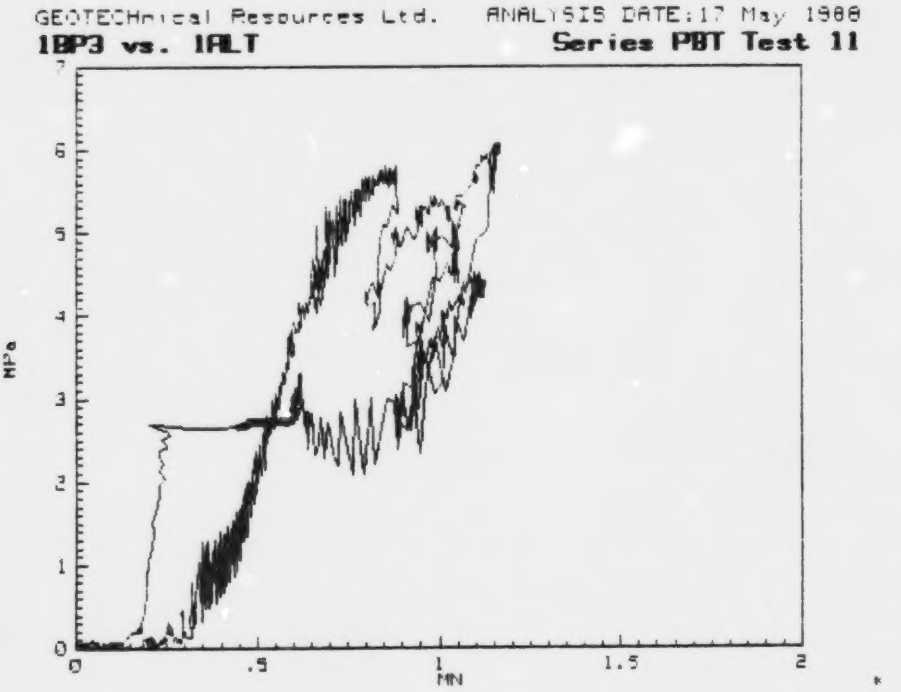


GEOTECHnical Resources Ltd.   ANALYSIS DATE:17 May 1988

Blade Surface Pressure   **Series PBT Test 11**

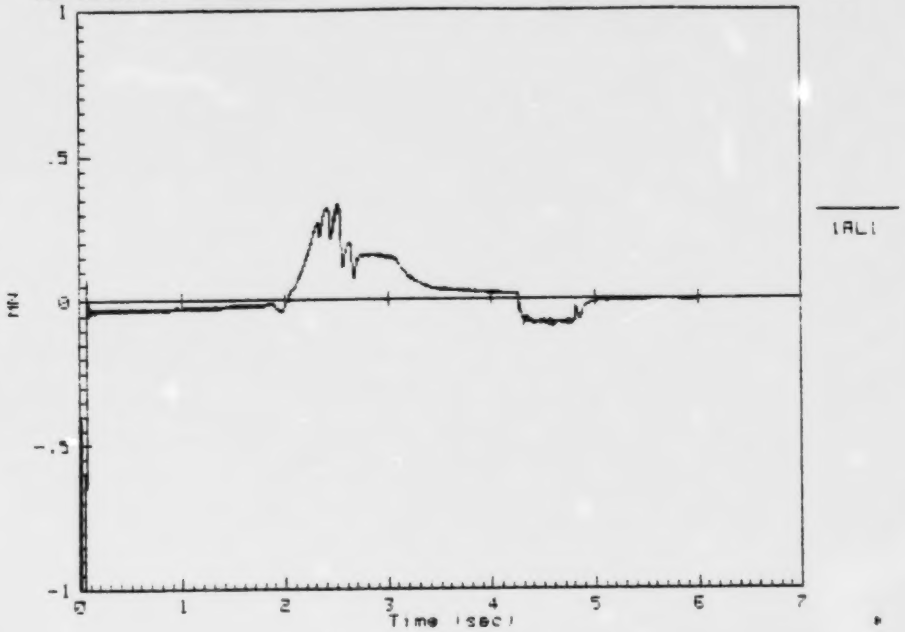



GEOTECHnical Resources Ltd.
ANALYSIS DATE: 17 May 1988
Blade Surface Pressure
Series PBT Test 11
.7
.6
.5
.4
.3
.2
.1
0
-.1
-.2
MPa
0
1
2
3
4
5
6
Time (sec)
1BPS


GEOTECHnical Resources Ltd.
ANALYSIS DATE: 17 May 1988
1BP3 vs. 1ALT
Series PBT Test 11
7
6
5
4
3
2
1
0
MPa
0
.5
1
1.5
2
MN

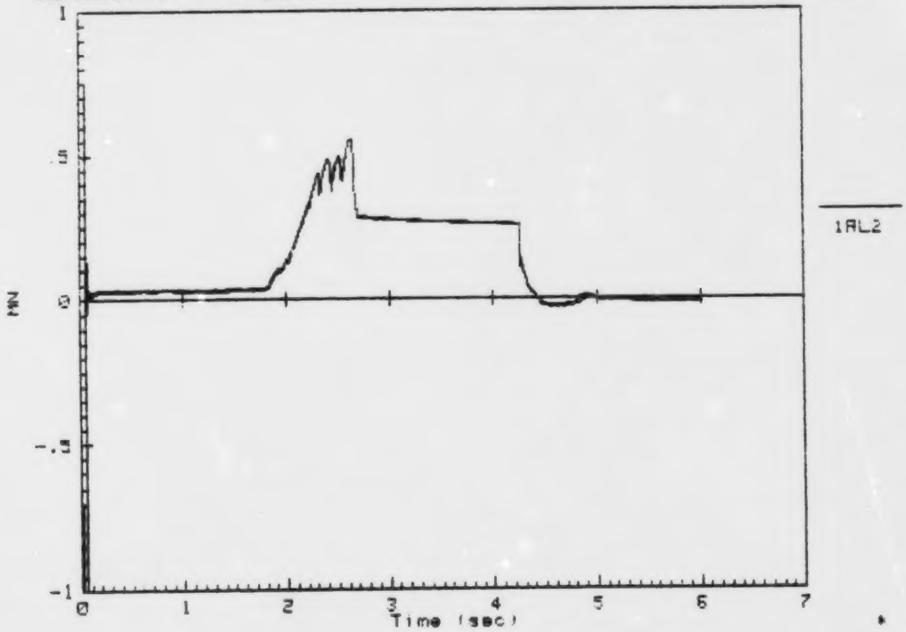
GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

Actuator 1 Load **Series PBT Test 11**



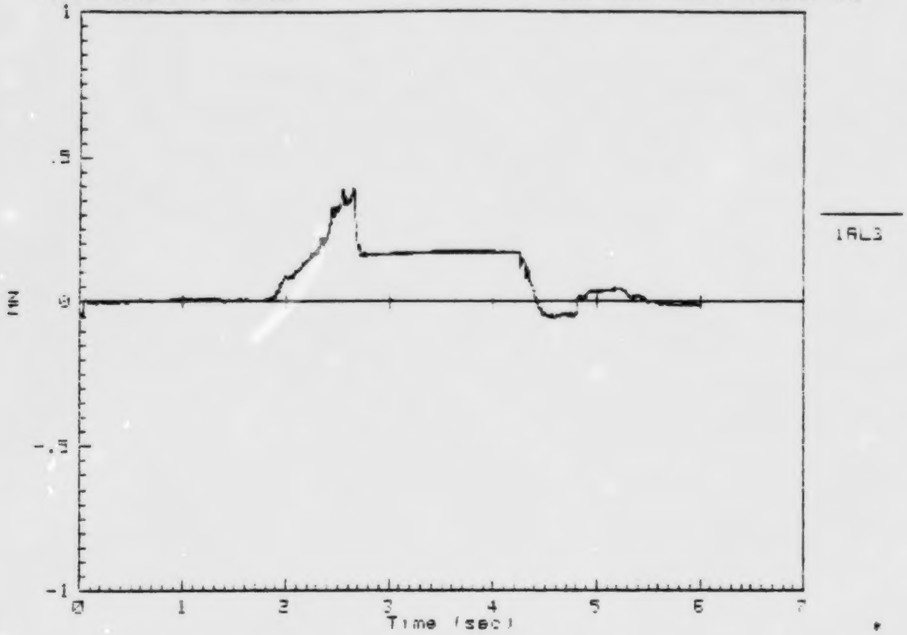
GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

Actuator 2 Load **Series PBT Test 11**



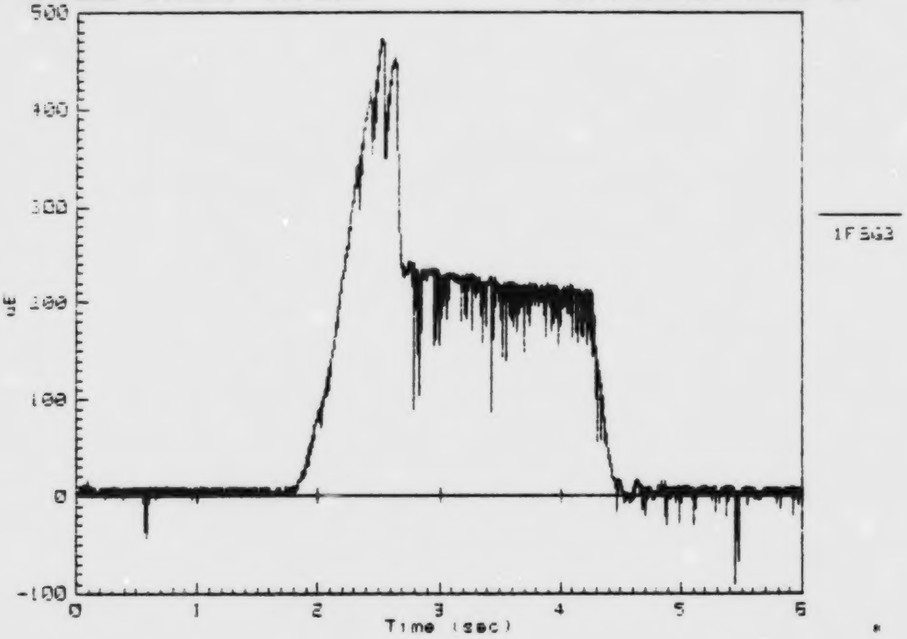
GEOTECHnical Resources Ltd.   ANALYSIS DATE:17 May 1988

Actuator 3 Load **Series PBT Test 11**



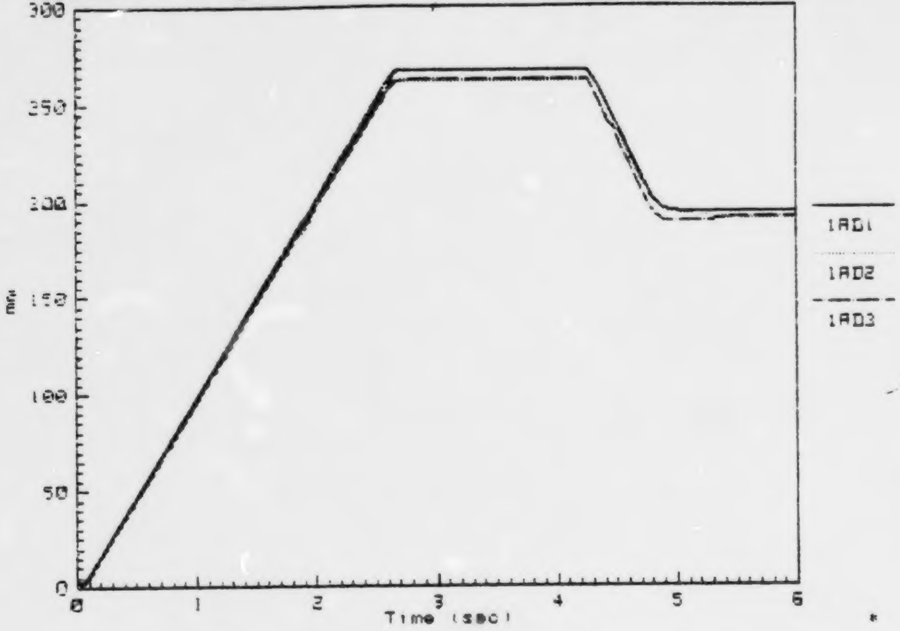
GEOTECHnical Resources Ltd.   ANALYSIS DATE:17 May 1988

Frame Girder Strain **Series PBT Test 11**



GEOTECHnical Resources Ltd. ANALYSIS DATE: 7 Jul 1988

Actuator Displacement **Series PBT Test 11**



$$d = \frac{300\text{ mm}}{3 - 0.2\text{ s}} = 100.7\text{ mm/s}$$

```
                         GEOTECHnical resources ltd
                                PROP BUSTERS
                           PROJECT NUMBER: 9448


Date: 18 May 1988
Time: 14:51:39

Test series...... PBT
Test number...... 12

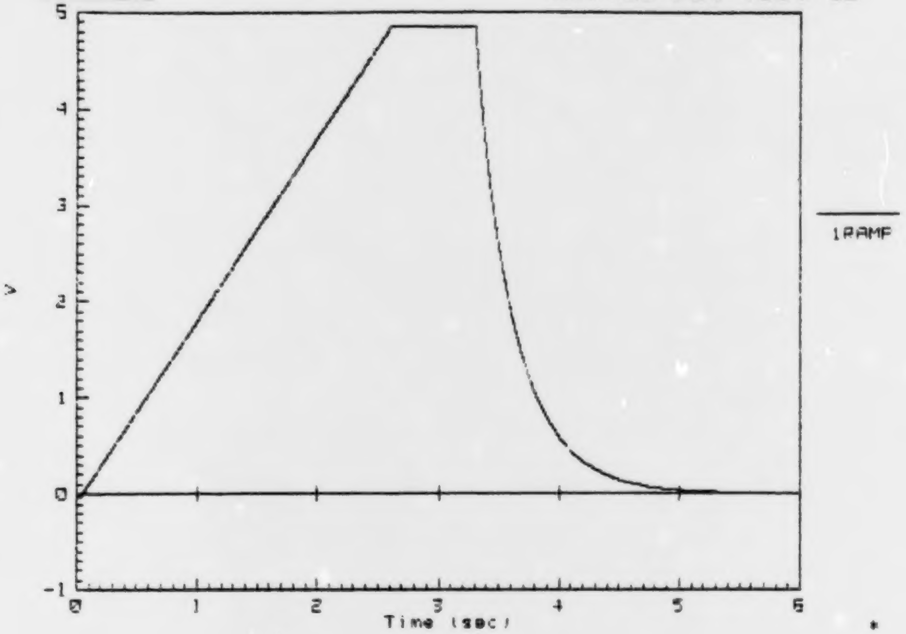
*** Window 1 ***
Test duration .................. 6 Second(s)
AD-200 sample period............ 16.1 Micro-second(s)
Sample rate, aggregate ......... 62111 Hz.
Sample rate per channel ........ 3881 Hz.
Number of samples per channel .. 23292 words.
Total number of samples ........ 745344 words.
Trigger source ................. INTERNAL
Number of cards ................ 2
Number of channels per card .... 16
Total number of channels ....... 32
```

Transducer table for test #PBT12_HDR

```
14750 Card1:!
14760   !-----¦--¦--¦--¦--¦----¦--------¦--------¦-------¦------¦---------¦
14770   !Card ¦Ch¦SW¦HW¦Ex¦Mode¦  Gain  ¦ Offset ¦ Units ¦  Ch  ¦  Serial ¦
14780   ! no. ¦no¦gn¦gn¦gn¦    ¦(eng/V)¦  (V)   ¦ (/V)  ¦  Id  ¦  Number ¦
14790   !-----¦--¦--¦--¦--¦----¦--------¦--------¦-------¦------¦---------¦
14800   DATA 1, 1, 1, 1, 1, "S",  107.29,  2.7124,   "mm", "BD1",  "A33380"
14810   DATA 1, 2, 1, 1, 1, "S",  107.42,  2.0726,   "mm", "BD2",  "A22090"
14820   DATA 1, 3, 1, 1, 1, "S",  107.42,  2.3608,   "mm", "BD3",  "A22091"
14830   DATA 1, 4, 1, 1, 1, "S",  6.8529,  0.0879,  "MPa","APR1",    "5817"
14840   DATA 1, 5, 1, 1, 1, "S",  6.8586,  0.0049,  "MPa","APE1",    "4986"
14850   DATA 1, 6, 1, 1, 1, "S",  6.8792,  0.0562,  "MPa","APR2",    "5723"
14860   DATA 1, 7, 1, 1, 1, "S",  6.8636,  0.0708,  "MPa","APE2",    "5815"
14870   DATA 1, 8, 1, 1, 1, "S",  6.8643,  0.0806,  "MPa","APR3",    "5883"
14880   DATA 1, 9, 1, 1, 1, "S",  6.8531,  0.0562,  "MPa","APE3",    "5885"
14890   DATA 1,10, 1, 1, 1, "S",  13.709,  0.0757,  "MPa", "BP1",    "5887"
14900   DATA 1,11, 1, 1, 1, "S",  13.712,  0.1025,  "MPa", "BP2",    "5773"
14910   DATA 1,12, 1, 1, 1, "S",  13.734,  0.0806,  "MPa", "BP3",    "5892"
14920   DATA 1,13, 1, 1, 1, "S",  13.731,  0.0708,  "MPa", "BP4",    "5869"
14930   DATA 1,14, 1, 1, 1, "S",  13.717,  0.0635,  "MPa", "BP5",    "5891"
14940   DATA 1,15, 1, 1, 2, "S",     1.0,       0,  "  V","RAMP",  "      "
14950   DATA 1,16, 1, 1, 1, "S",  1000.0,       0,   "uE","BR1B",  "      "
14960 Card2:!
14970   DATA 2, 1 ,1, 1, 2, "S",  53.906,  1.3525,   "mm", "AD1",  "A22091"
14980   DATA 2, 2, 1, 1, 2, "S",  53.634,  1.3379,   "mm", "AD2",  "A33381"
14990   DATA 2, 3, 1, 1, 2, "S",  53.608,  1.4599,   "mm", "AD3",  "A33382"
15000   DATA 2, 4, 1, 1, 1, "S",  1000.0,       0,   "uE","BR1A",  "      "
15010   DATA 2, 5, 1, 1, 1, "S",  1000.0,       0,   "uE","BR2A",  "      "
15020   DATA 2, 6, 1, 1, 1, "S",  1000.0,       0,   "uE","FSG3",  "      "
15030   DATA 2, 7, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS7",  "      "
15040   DATA 2, 8, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS8",  "      "
15050   DATA 2, 9, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS9",  "      "
15060   DATA 2,10, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS1",  "      "
15070   DATA 2,11, 1, 1, 1, "S",  1000.0,       0,   "uE","BR2B",  "      "
15080   DATA 2,12, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS3",  "      "
15090   DATA 2,13, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS4",  "      "
15100   DATA 2,14, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS2",  "      "
15110   DATA 2,15, 1, 1, 1, "S",  1000.0,  0.2881,   "uE","BR2C",  "      "
15120   DATA 2,16, 1, 1, 1, "S",  1000.0,       0,   "uE","BR1C",  "      "
15130   !-----¦--¦--¦--¦--¦----¦--------¦--------¦-------¦------¦---------¦
15140   !Card ¦Ch¦SW¦HW¦Ex¦Mode¦  Gain  ¦ Offset ¦ Units ¦  Ch  ¦  Serial ¦
15150   ! no. ¦no¦gn¦gn¦gn¦    ¦(Eng/V)¦  (V)   ¦ (/V)  ¦  Id  ¦  Number ¦
15160   !-----¦--¦--¦--¦--¦----¦--------¦--------¦-------¦------¦---------¦
15170 End_transducers:!
```

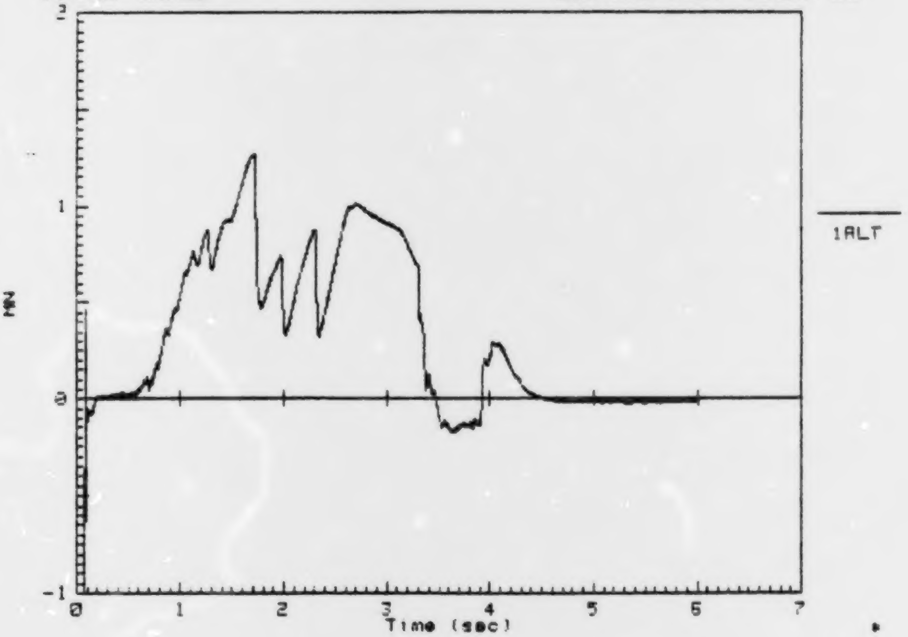
GEOTECHnical Resources Ltd.   ANALYSIS DATE: 18 May 1988

Command   **Series PBT Test 12**



GEOTECHnical Resources Ltd.   ANALYSIS DATE: 18 May 1988

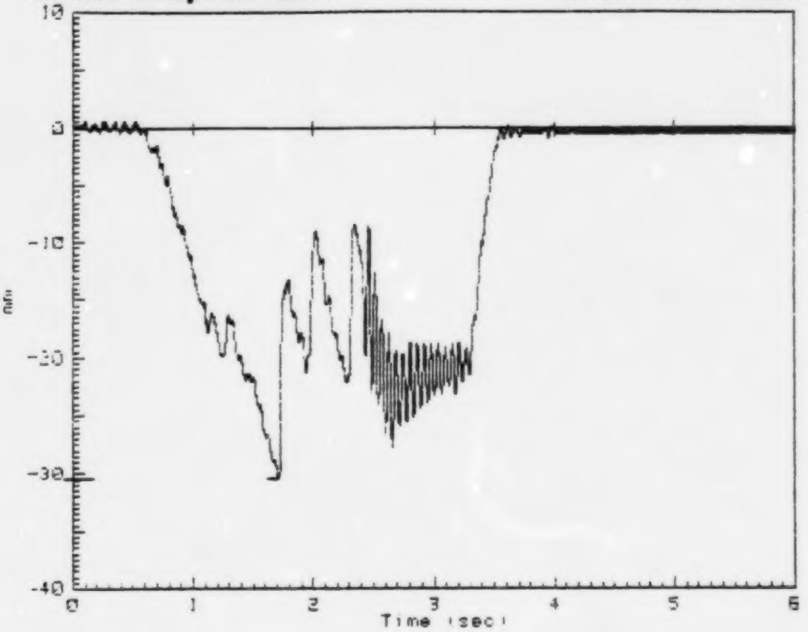
Total Load   **Series PBT Test 12**



Peak load
≈ 1.27 MN
@ ≈ 1.7 s

GEOTECHnical Resources Ltd.   ANALYSIS DATE:18 May 1988

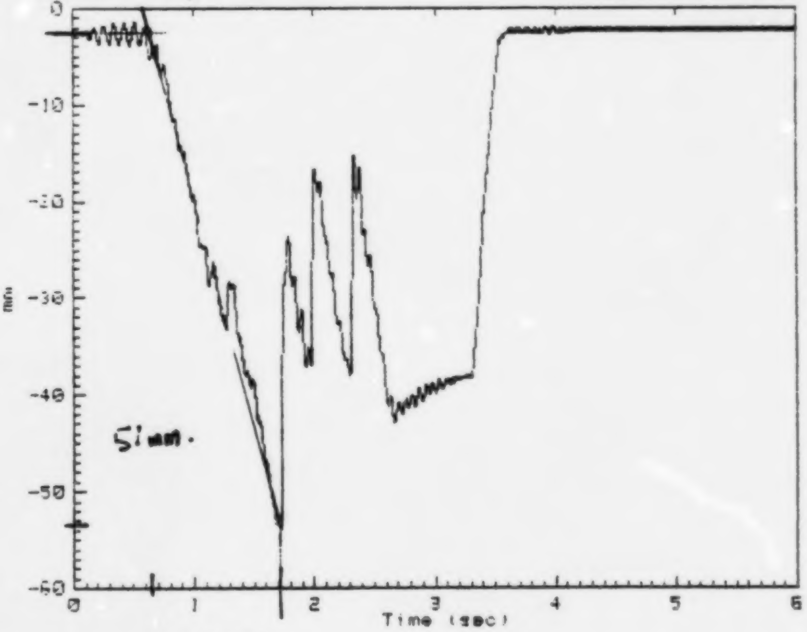
Blade Displacement   **Series PBT Test 12**



18D1

GEOTECHnical Resources Ltd.   ANALYSIS DATE:18 May 1988

Blade Displacement   **Series PBT Test 12**

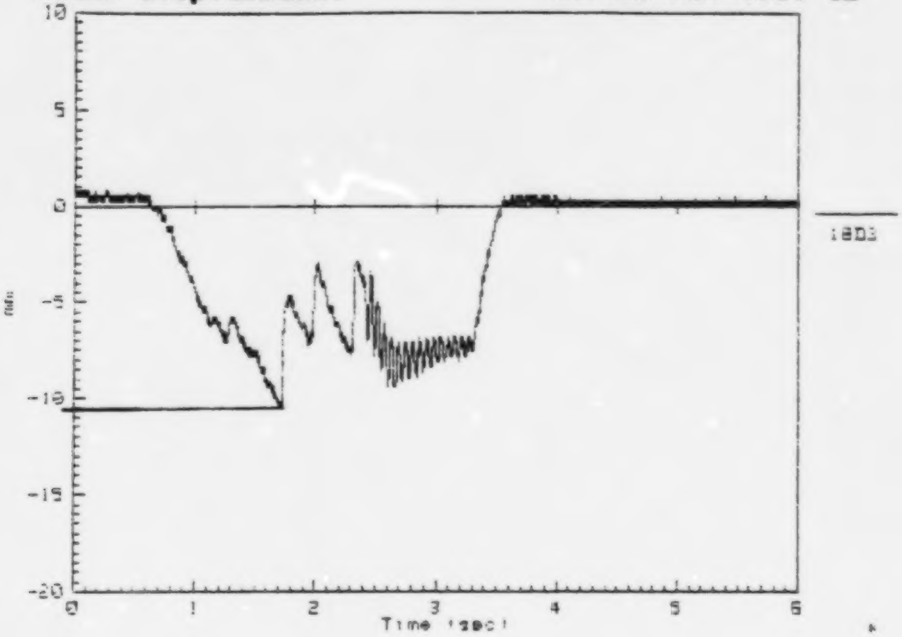


18D2

1.05s.

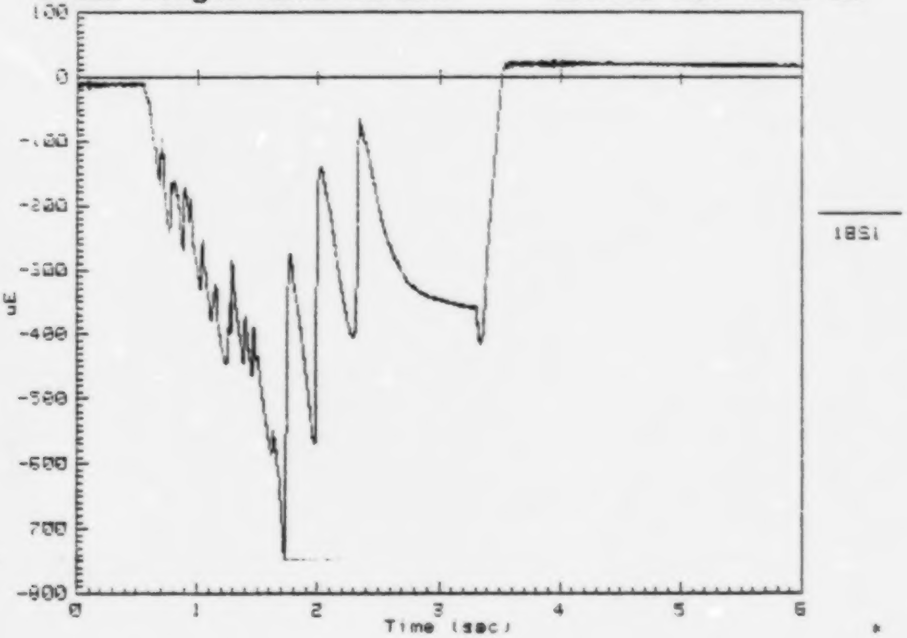
GEOTECHnical Resources Ltd.   ANALYSIS DATE:18 May 1988

Blade Displacement   Series PBT Test 12



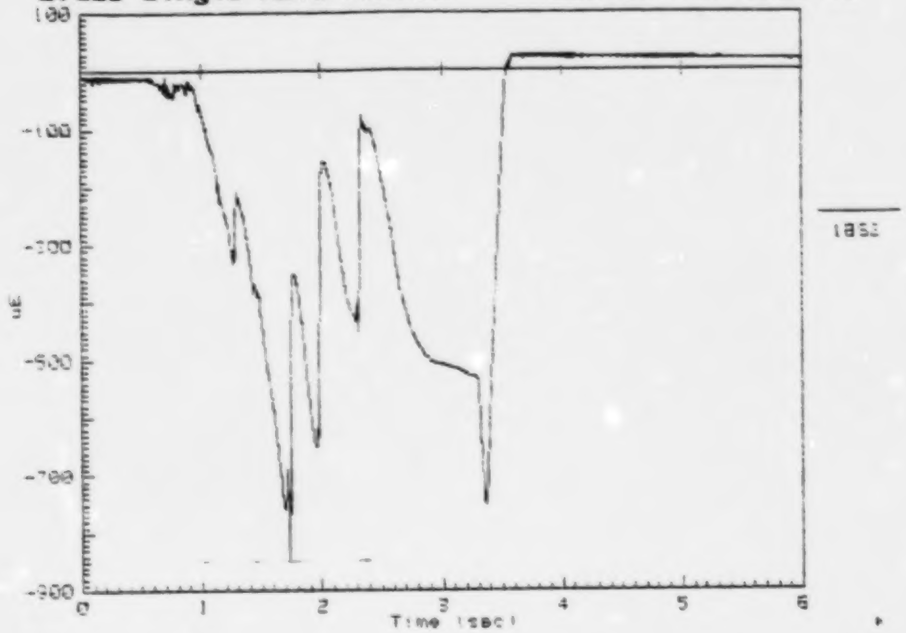
GEOTECHnical Resources Ltd.   ANALYSIS DATE:18 May 1988

Blade Single-Axis Strain   Series PBT Test 12



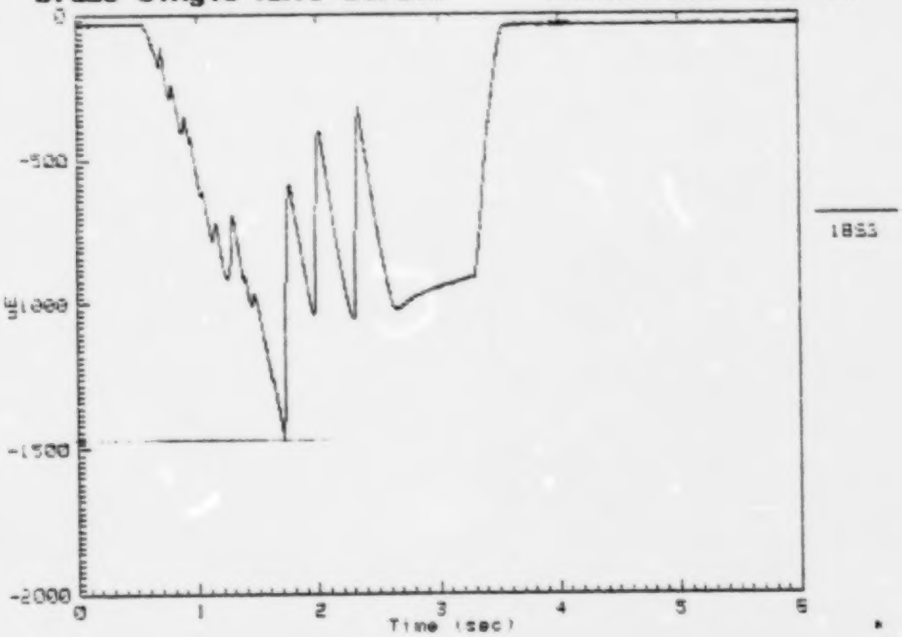
GEOTECHnical Resources Ltd.   ANALYSIS DATE: 18 May 1988

Blade Single-Axis Strain   Series PBT Test 12



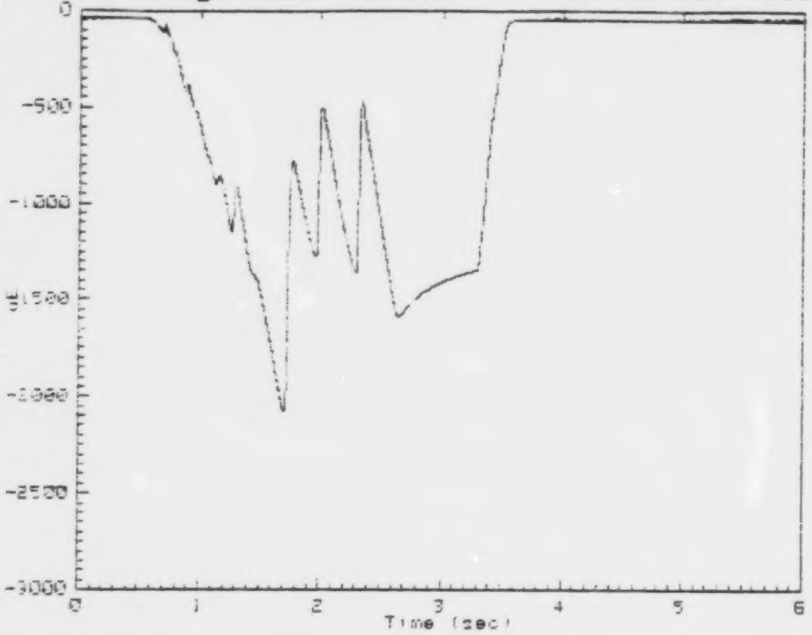
GEOTECHnical Resources Ltd.   ANALYSIS DATE: 18 May 1988

Blade Single-Axis Strain   Series PBT Test 12



GEOTECHnical Resources Ltd. ANALYSIS DATE: 18 May 1988

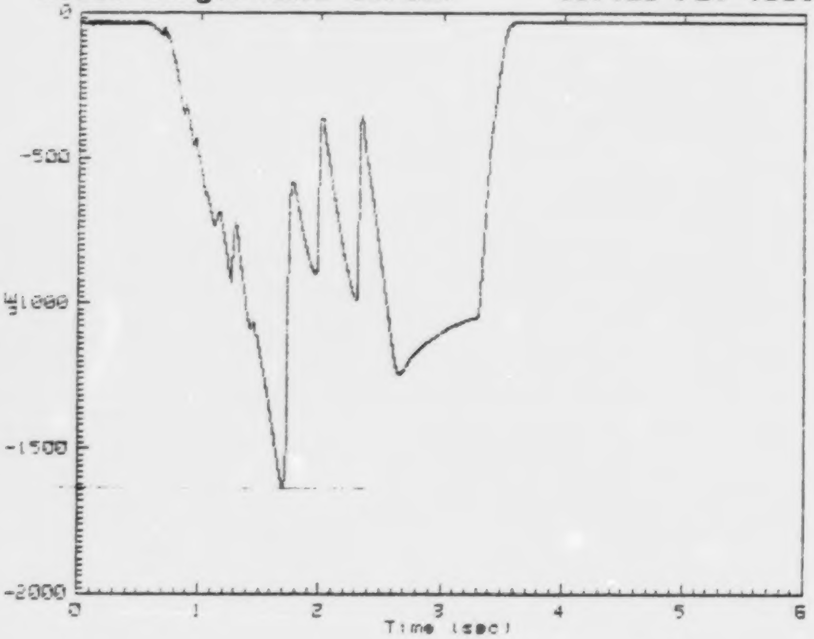
Blade Single-Axis Strain **Series PBT Test 12**



1654

GEOTECHnical Resources Ltd. ANALYSIS DATE: 18 May 1988

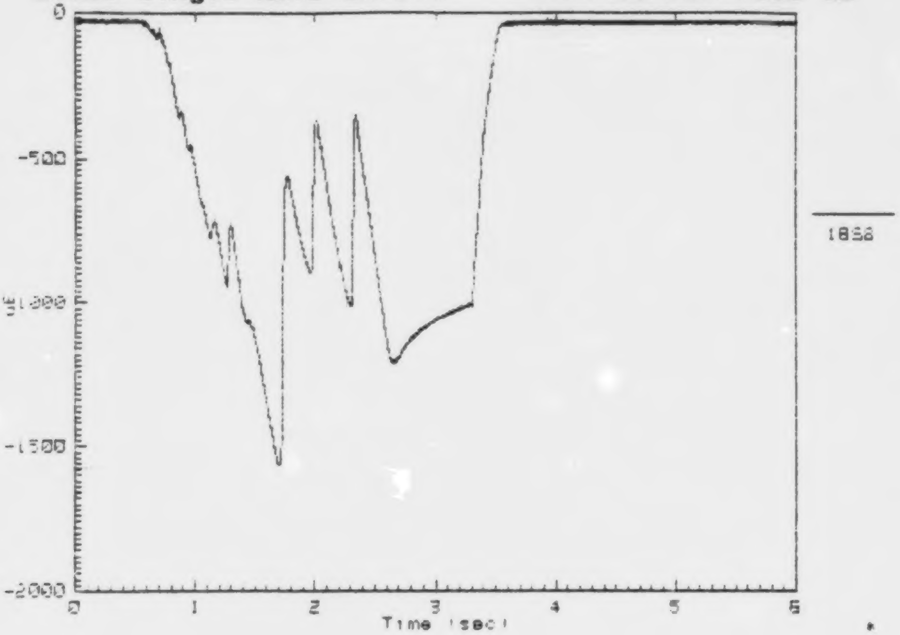
Blade Single-Axis Strain **Series PBT Test 12**



1857

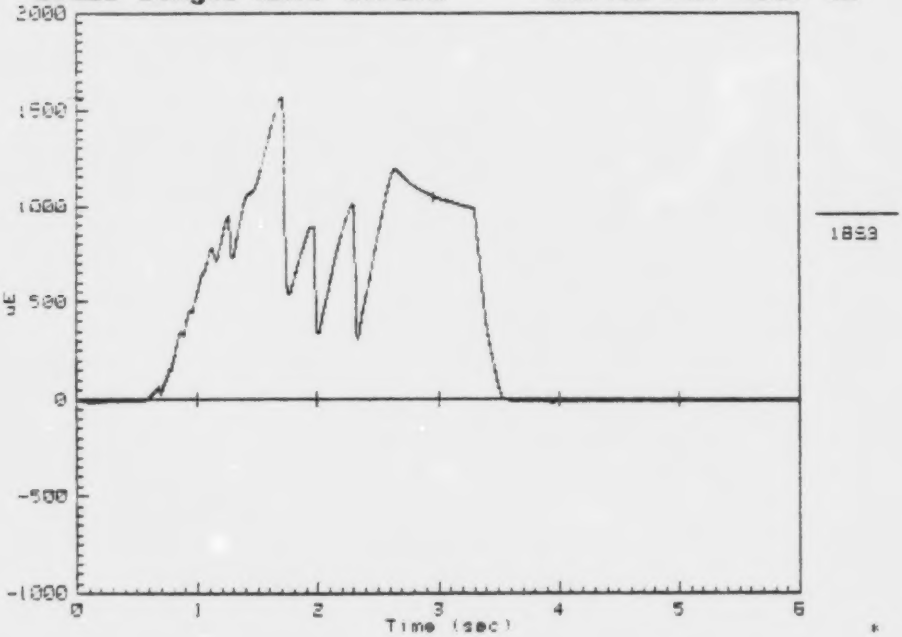
GEOTECHnical Resources Ltd. ANALYSIS DATE: 18 May 1988

Blade Single-Axis Strain **Series PBT Test 12**



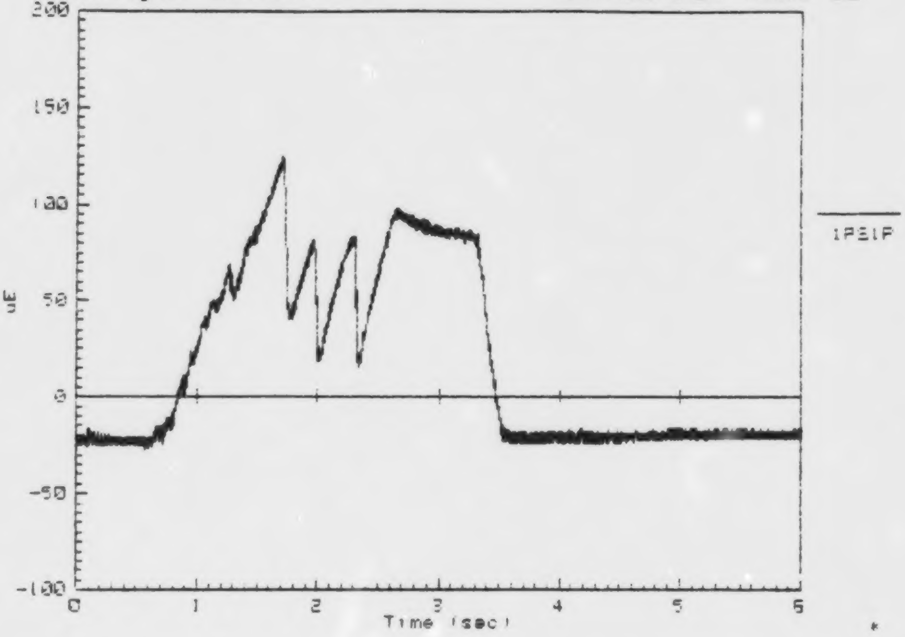
GEOTECHnical Resources Ltd. ANALYSIS DATE: 18 May 1988

Blade Single-Axis Strain **Series PBT Test 12**



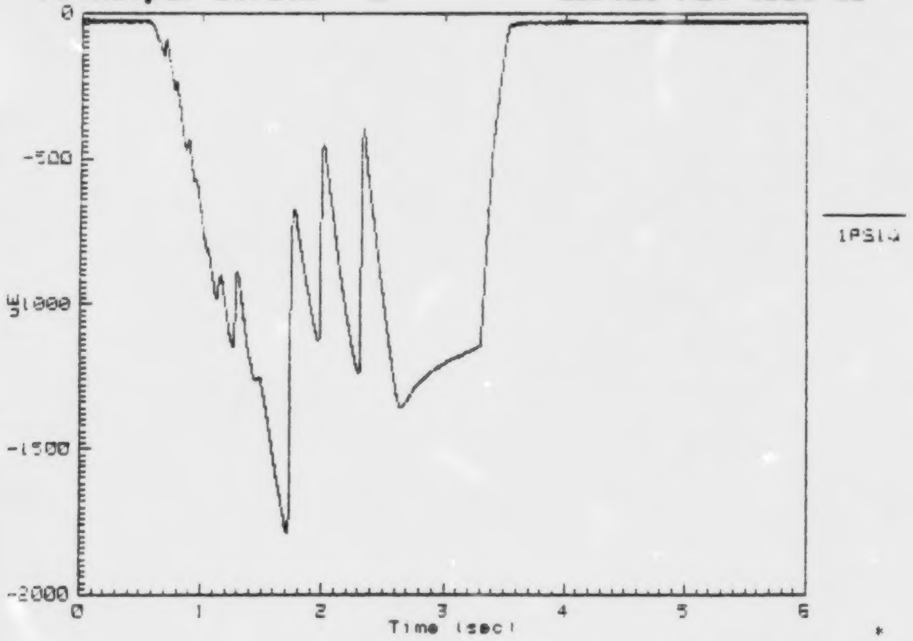
GEOTECHnical Resources Ltd. ANALYSIS DATE: 18 May 1988

Principal Strain - P **Series PBT Test 12**



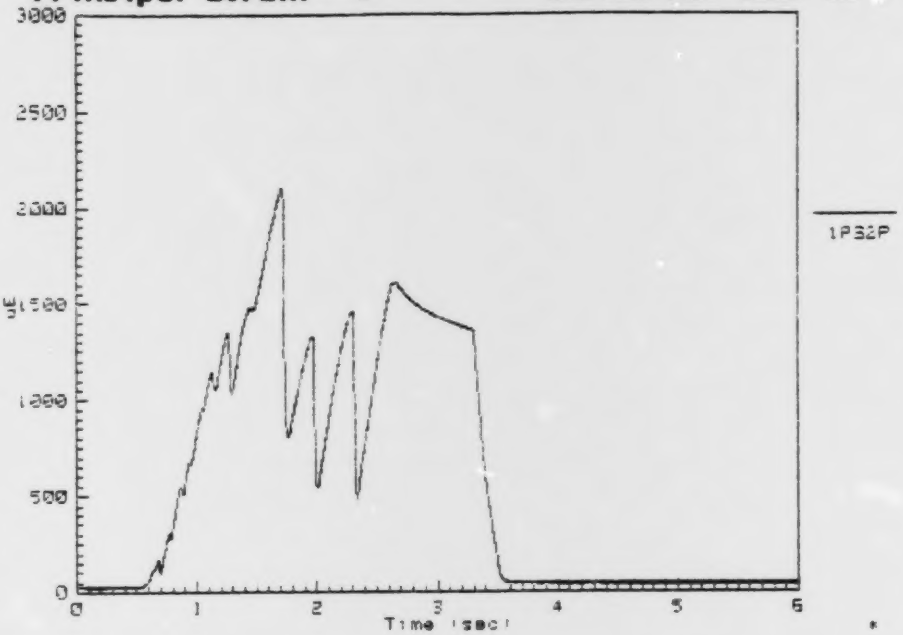
GEOTECHnical Resources Ltd. ANALYSIS DATE: 18 May 1988

Principal Strain - Q **Series PBT Test 12**



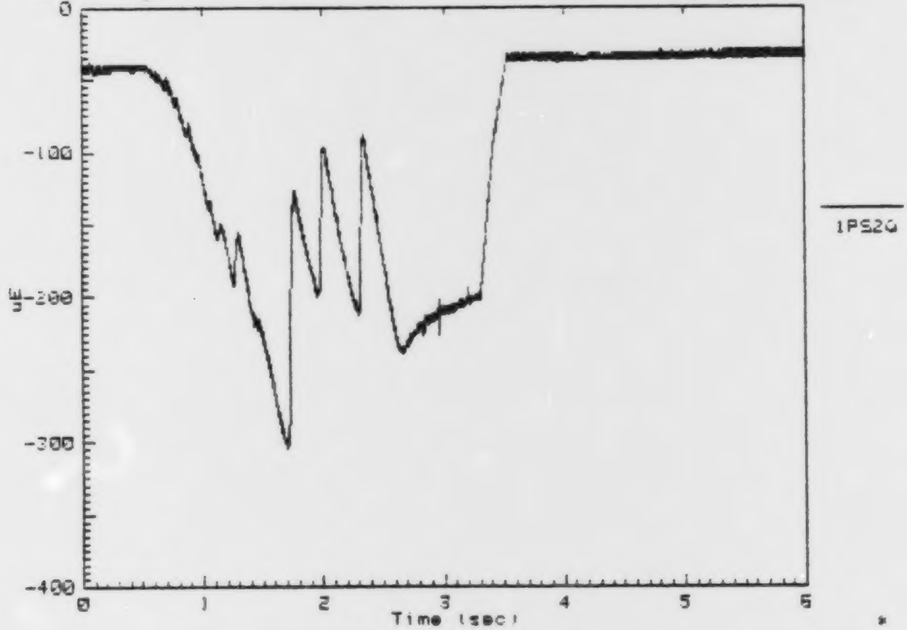
GEOTECHnical Resources Ltd. ANALYSIS DATE:10 May 1988

Principal Strain – P **Series PBT Test 12**



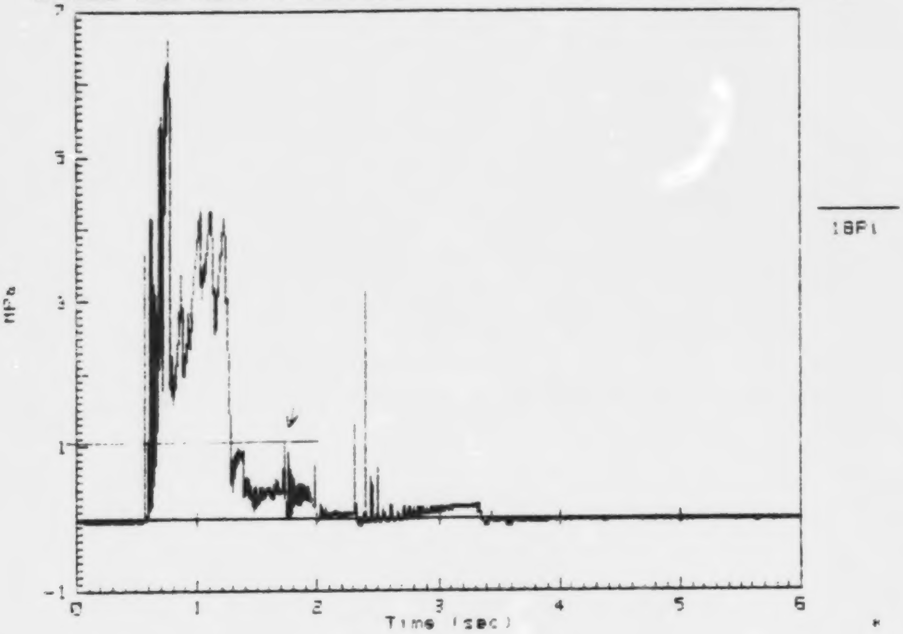
GEOTECHnical Resources Ltd. ANALYSIS DATE:10 May 1988

Principal Strain – Q **Series PBT Test 12**



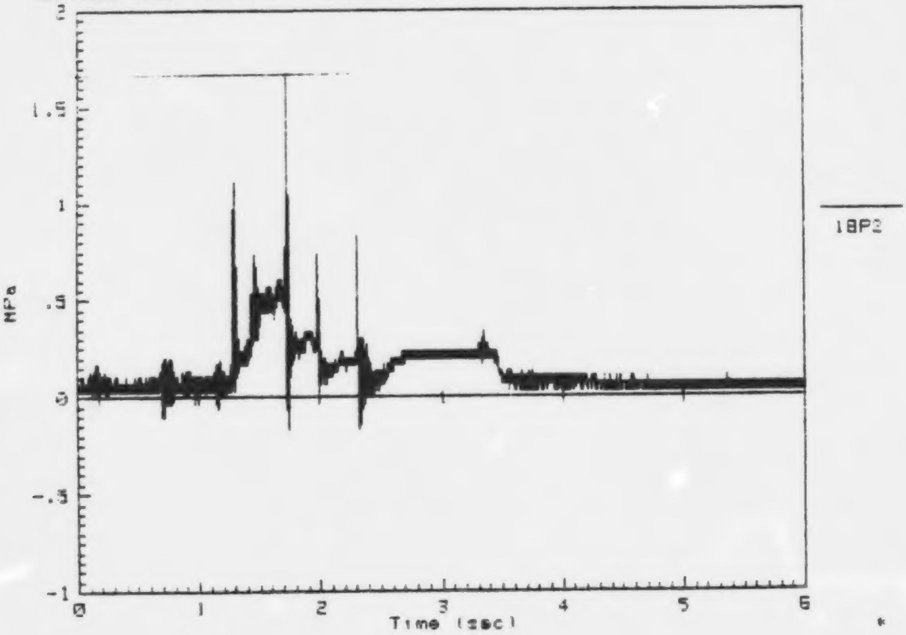
GEOTECHnical Resources Ltd. ANALYSIS DATE: 18 May 1988

Blade Surface Pressure **Series PBT Test 12**



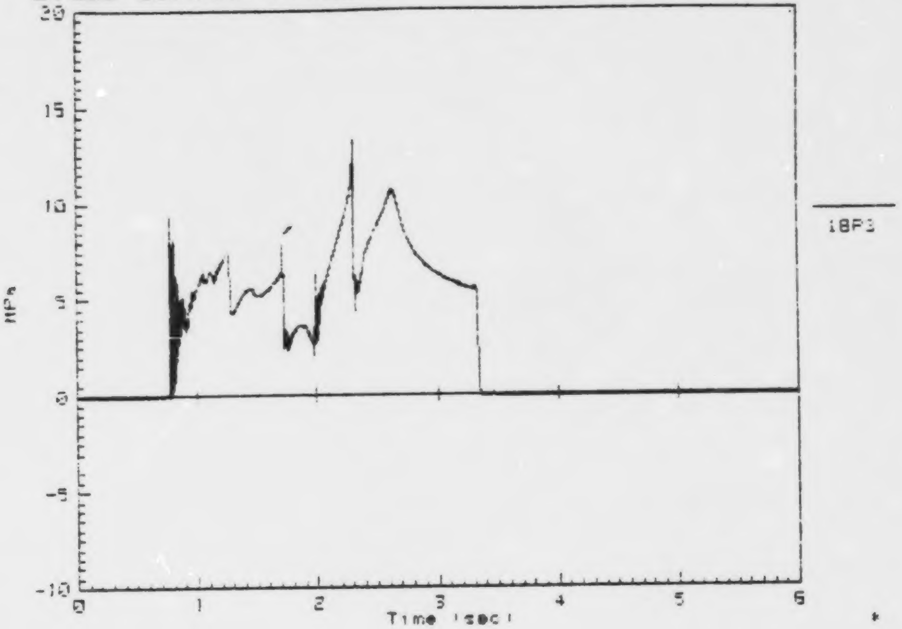
GEOTECHnical Resources Ltd. ANALYSIS DATE: 18 May 1988

Blade Surface Pressure **Series PBT Test 12**



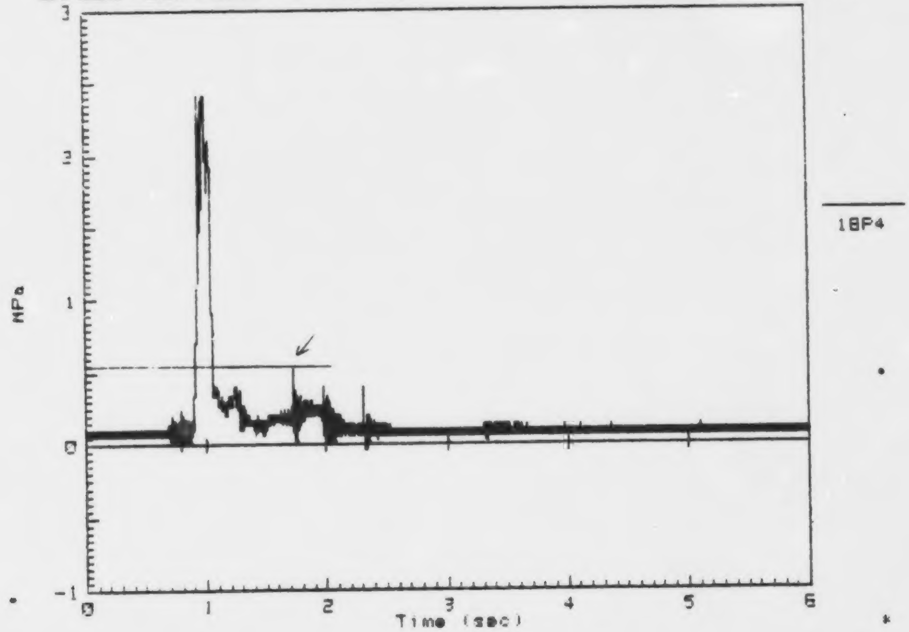
GEOTECHnical Resources Ltd. ANALYSIS DATE:18 May 1988

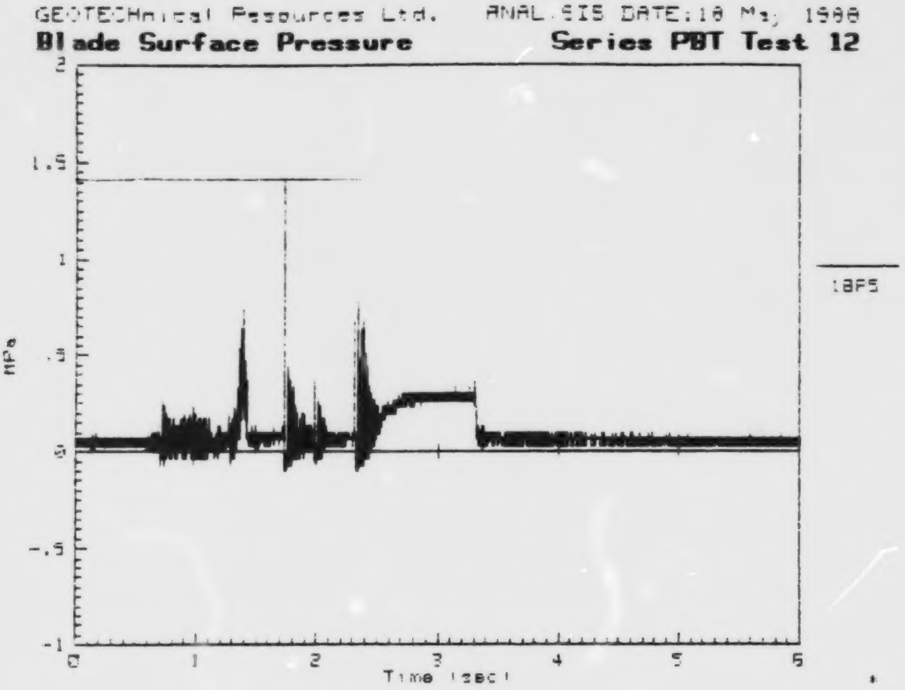
Blade Surface Pressure **Series PBT Test 12**

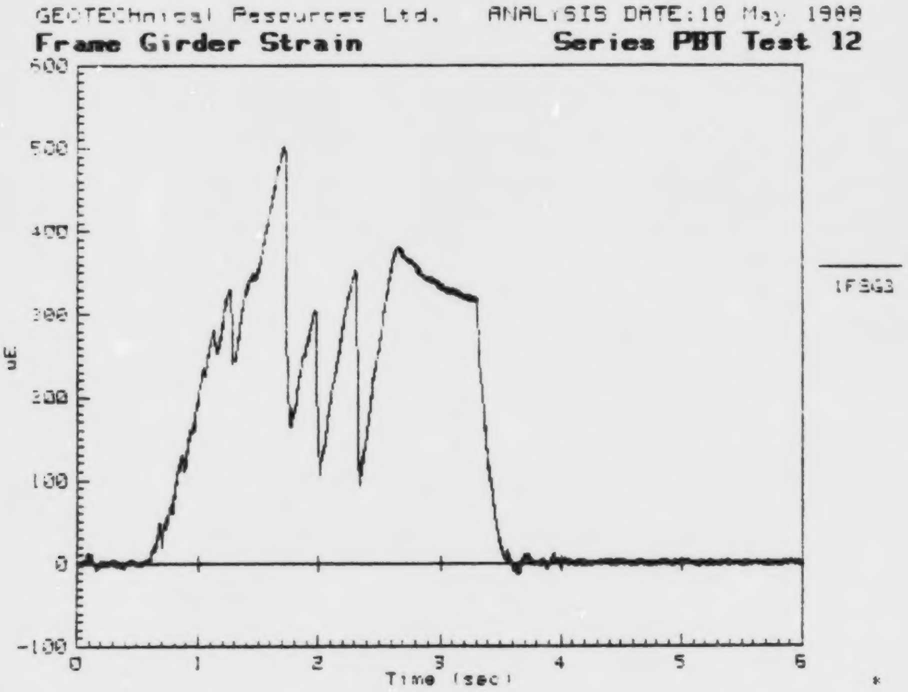


GEOTECHnical Resources Ltd. ANALYSIS DATE:18 May 1988

Blade Surface Pressure **Series PBT Test 12**

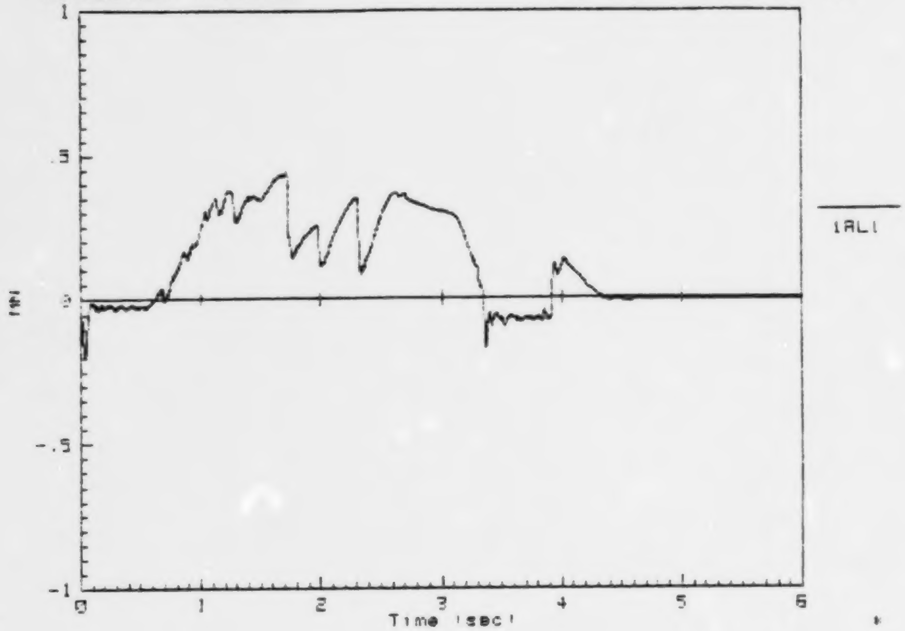



GEOTECHnical Resources Ltd.
ANALYSIS DATE:10 May 1988
Blade Surface Pressure
Series PBT Test 12
MPa
2
1.5
1
.5
0
-.5
-1
0
1
2
3
4
5
6
Time (sec)
1BPS


GEOTECHnical Resources Ltd.
ANALYSIS DATE:10 May 1988
Frame Girder Strain
Series PBT Test 12
uE
600
500
400
300
200
100
0
-100
0
1
2
3
4
5
6
Time (sec)
1FSG3

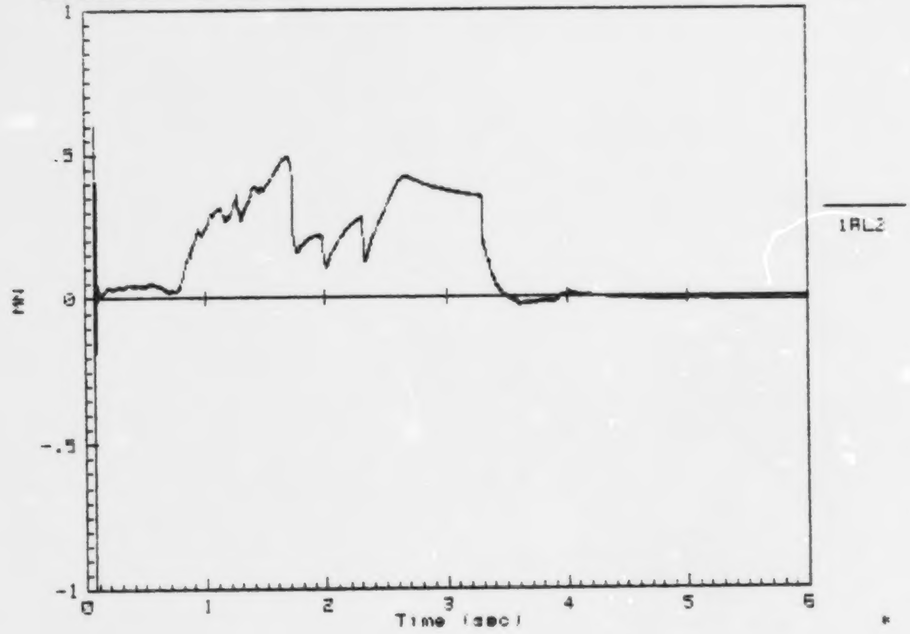
GEOTECHnical Resources Ltd. ANALYSIS DATE:18 May 1988

Actuator 1 Load **Series PBT Test 12**



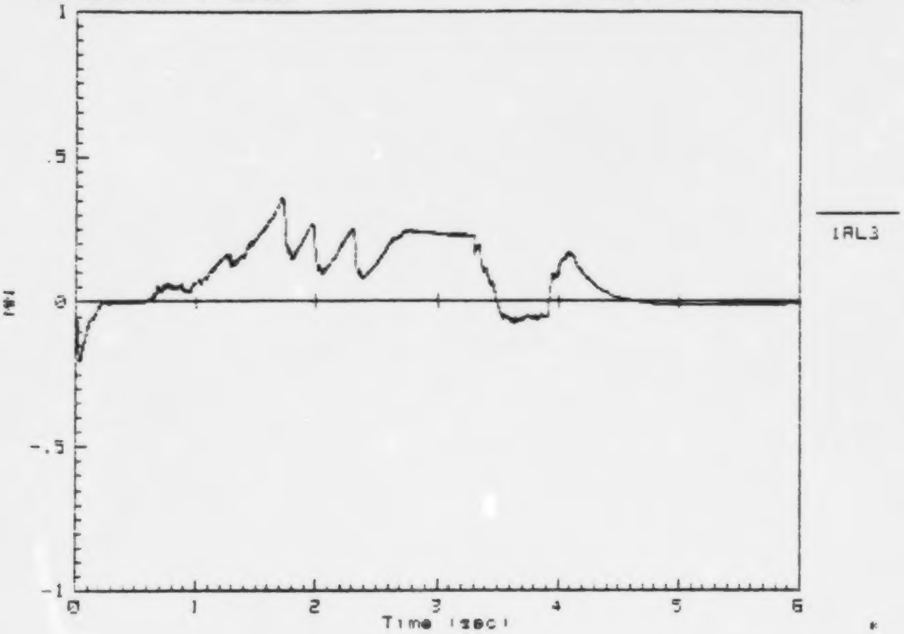
GEOTECHnical Resources Ltd. ANALYSIS DATE:18 May 1988

Actuator 2 Load **Series PBT Test 12**



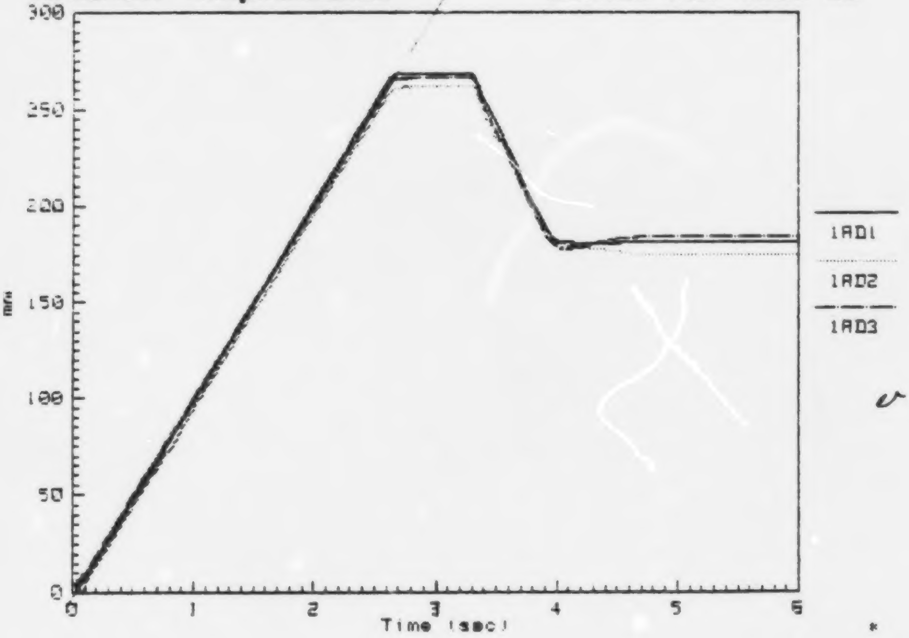
GEOTECHnical Resources Ltd. ANALYSIS DATE: 18 May 1988

Actuator 3 Load **Series PBT Test 12**



GEOTECHnical Resources Ltd. ANALYSIS DATE: 18 May 1988

Actuator Displacement **Series PBT Test 12**

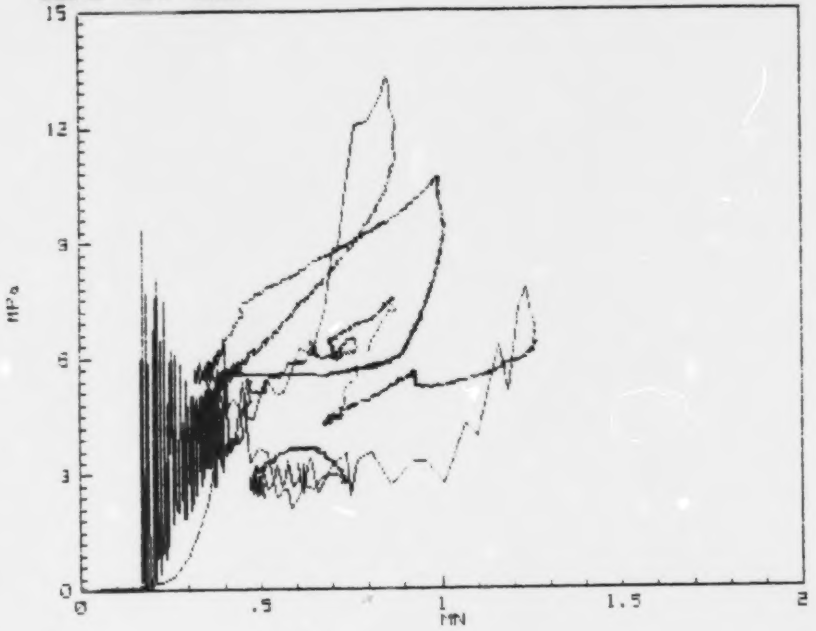


$v = \frac{300mm}{(3-0.2)s}$

$= 100.7\ mm/s$

GEOTECHnical Resources Ltd.   ANALYSIS DATE:18 May 1988

1BP3 vs. 1ALT   **Series PBT Test 12**



GEOTECHnical resources ltd
PROP BUSTERS
PROJECT NUMBER: 9448

```
Date: 19 May 1988
Time: 13:35:25

Test series...... PBT
Test number...... 14

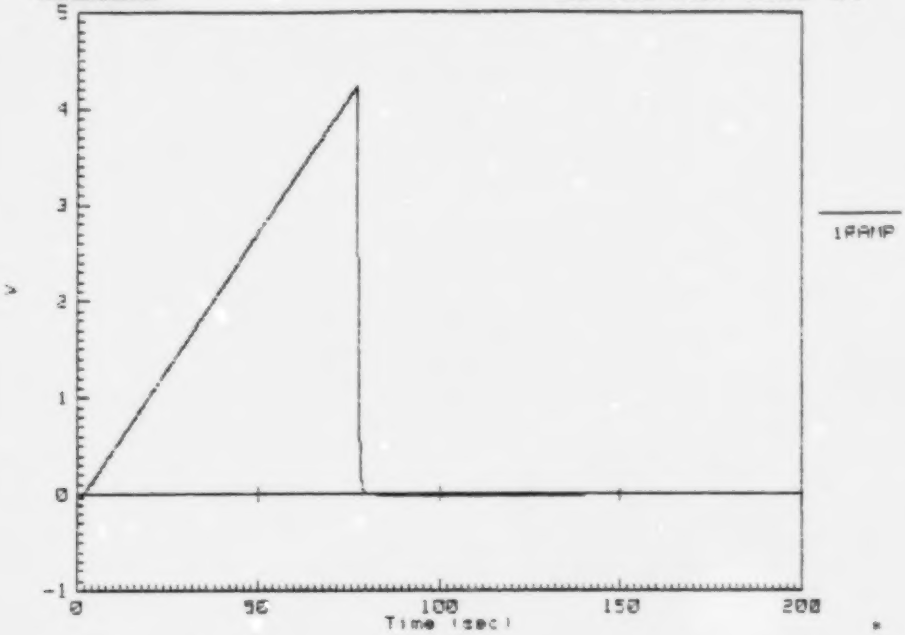
*** Window 1 ***
Test duration .................. 140 Second(s)
AD-200 sample period............ 277.75 Micro-second(s)
Sample rate, aggregate ......... 3600 Hz.
Sample rate per channel ........ 225 Hz.
Number of samples per channel .. 31504 words.
Total number of samples ........ 1.008128E+6 words.
Trigger source ................. INTERNAL
Number of cards ................ 2
Number of channels per card .... 16
Total number of channels ....... 32
```

Transducer table for test #P6T14_HDR

```
14750 Card1:!
14760    |-----|--|--|--|--|----|--------|--------|-------|------|---------|
14770    |Card |Ch|SW|HW|Ex|Mode|  Gain  | Offset | Units |  Ch  |  Serial |
14780    | no. |no|gn|gn|gn|    | (eng/V)|  (V)   | (/V)  |  Id  |  Number |
14790    |-----|--|--|--|--|----|--------|--------|-------|------|---------|
14800    DATA 1, 1, 1, 1, 1, "S",  107.29,  2.7124,   "mm", "BD1",  "A33380"
14810    DATA 1, 2, 1, 1, 1, "S",  107.42,  2.0726,   "mm", "BD2",  "A22090"
14820    DATA 1, 3, 1, 1, 1, "S",  107.42,  2.3608,   "mm", "BD3",  "A22091"
14830    DATA 1, 4, 1, 1, 1, "S",  6.8529,  0.0879,  "MPa","APR1",    "5817"
14840    DATA 1, 5, 1, 1, 1, "S",  6.8586,  0.0049,  "MPa","APE1",    "4986"
14850    DATA 1, 6, 1, 1, 1, "S",  6.8792,  0.0562,  "MPa","APR2",    "5723"
14860    DATA 1, 7, 1, 1, 1, "S",  6.8636,  0.0708,  "MPa","APE2",    "5815"
14870    DATA 1, 8, 1, 1, 1, "S",  6.8643,  0.0806,  "MPa","APR3",    "5883"
14880    DATA 1, 9, 1, 1, 1, "S",  6.8531,  0.0562,  "MPa","APE3",    "5885"
14890    DATA 1,10, 1, 1, 1, "S",  13.709,  0.0757,  "MPa", "BP1",    "5887"
14900    DATA 1,11, 1, 1, 1, "S",  13.712,  0.1025,  "MPa", "BP2",    "5773"
14910    DATA 1,12, 1, 1, 1, "S",  13.734,  0.0806,  "MPa", "BP3",    "5892"
14920    DATA 1,13, 1, 1, 1, "S",  13.731,  0.0708,  "MPa", "BP4",    "5889"
14930    DATA 1,14, 1, 1, 1, "S",  13.717,  0.0635,  "MPa", "BP5",    "5891"
14940    DATA 1,15, 1, 1, 2, "S",     1.0,       0, "  V","RAMP",   "     "
14950    DATA 1,16, 1, 1, 1, "S",  1000.0,       0,   "uE","BR1B",  "     "
14960 Card2:!
14970    DATA 2, 1 ,1, 1, 2, "S",  53.906,  1.3525,   "mm", "AD1",  "A22091"
14980    DATA 2, 2, 1, 1, 2, "S",  53.634,  1.3379,   "mm", "AD2",  "A33381"
14990    DATA 2, 3, 1, 1, 2, "S",  53.608,  1.4599,   "mm", "AD3",  "A33382"
15000    DATA 2, 4, 1, 1, 1, "S",  1000.0,       0,   "uE","BR1A",  "     "
15010    DATA 2, 5, 1, 1, 1, "S",  1000.0,       0,   "uE","BR2A",  "     "
15020    DATA 2, 6, 1, 1, 1, "S",  1000.0,       0,   "uE","FSG3",  "     "
15030    DATA 2, 7, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS7",  "     "
15040    DATA 2, 8, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS8",  "     "
15050    DATA 2, 9, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS9",  "     "
15060    DATA 2,10, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS1",  "     "
15070    DATA 2,11, 1, 1, 1, "S",  1000.0,       0,   "uE","BR2B",  "     "
15080    DATA 2,12, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS3",  "     "
15090    DATA 2,13, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS4",  "     "
15100    DATA 2,14, 1, 1, 1, "S",  1000.0,       0,   "uE", "BS2",  "     "
15110    DATA 2,15, 1, 1, 1, "S",  1000.0,  0.2881,   "uE","BR2C",  "     "
15120    DATA 2,16, 1, 1, 1, "S",  1000.0,       0,   "uE","BR1C",  "     "
15130    |-----|--|--|--|--|----|--------|--------|-------|------|---------|
15140    |Card |Ch|SW|HW|Ex|Mode|  Gain  | Offset | Units |  Ch  |  Serial |
15150    | no. |no|gn|gn|gn|    | (Eng/V)|  (V)   | (/V)  |  Id  |  Number |
15160    |-----|--|--|--|--|----|--------|--------|-------|------|---------|
15170 End_transducers:!
```

GEOTECHnical Resources Ltd.   ANALYSIS DATE:19 May 1988

Command   **Series PBT Test 14**

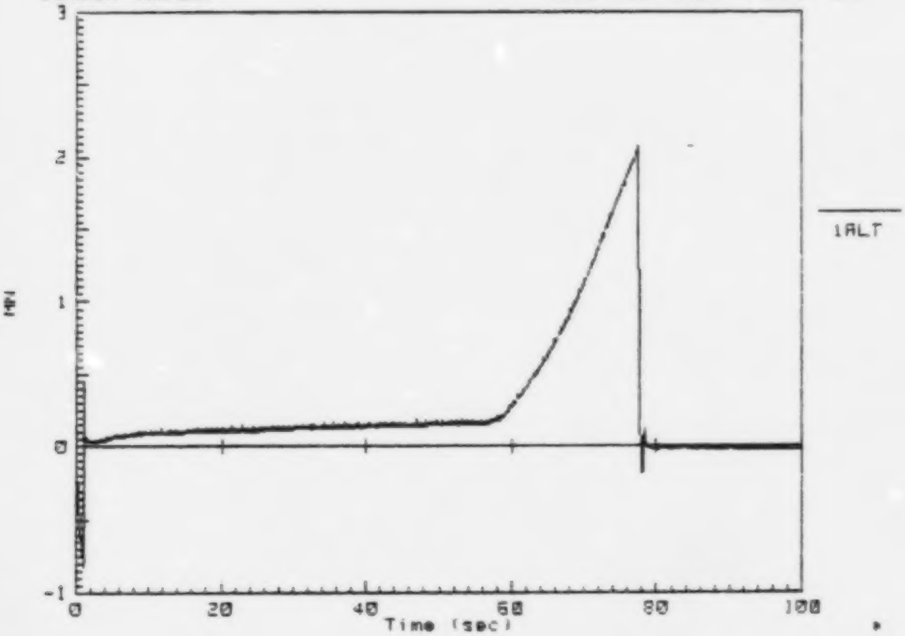


[illegible]

[illegible]

GEOTECHnical Resources Ltd.   ANALYSIS DATE:19 May 1988

Total Load   **Series PBT Test 14**



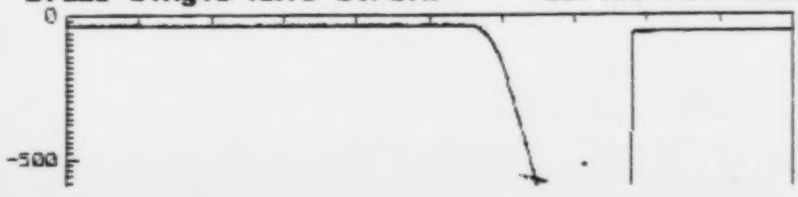
[illegible]

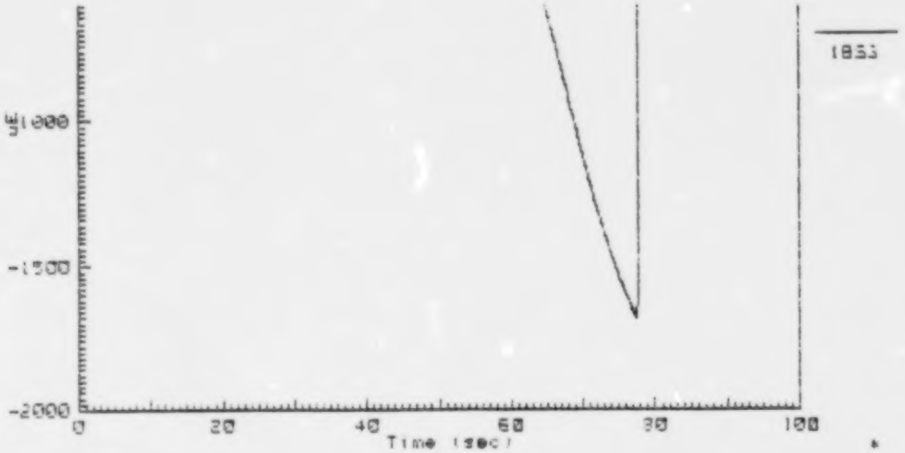
[illegible]

[illegible] 782

GEOTECHnical Resources Ltd.   ANALYSIS DATE:19 May 1988

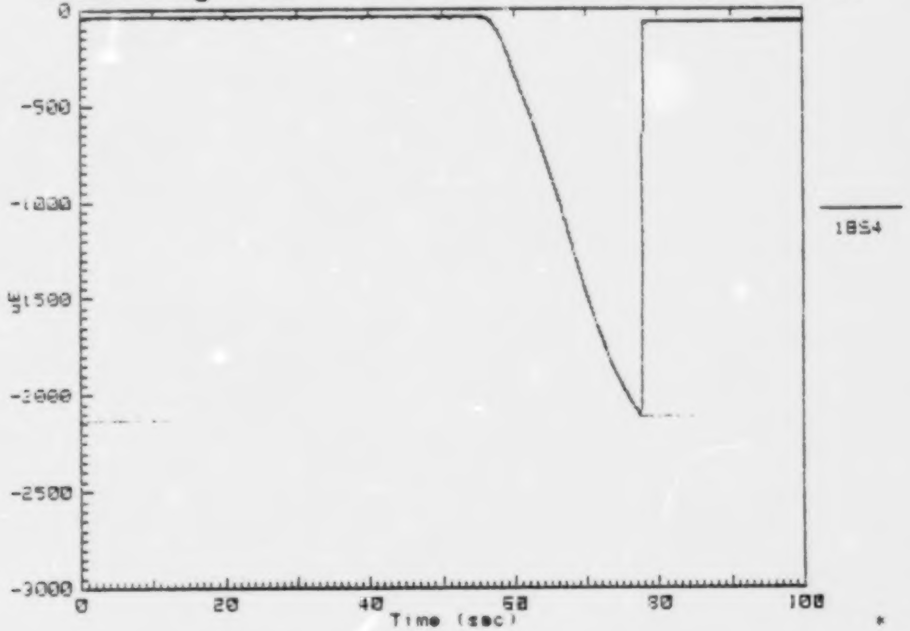
Blade Single-Axis Strain   **Series PBT Test 14**





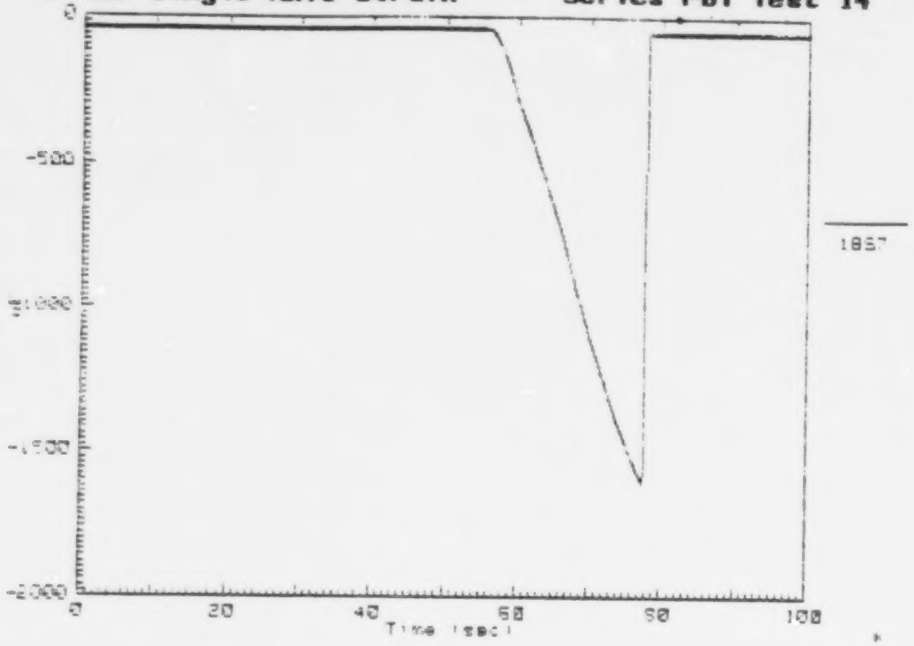
GEOTECHnical Resources Ltd.   ANALYSIS DATE:19 May 1988

Blade Single-Axis Strain   Series PBT Test 14



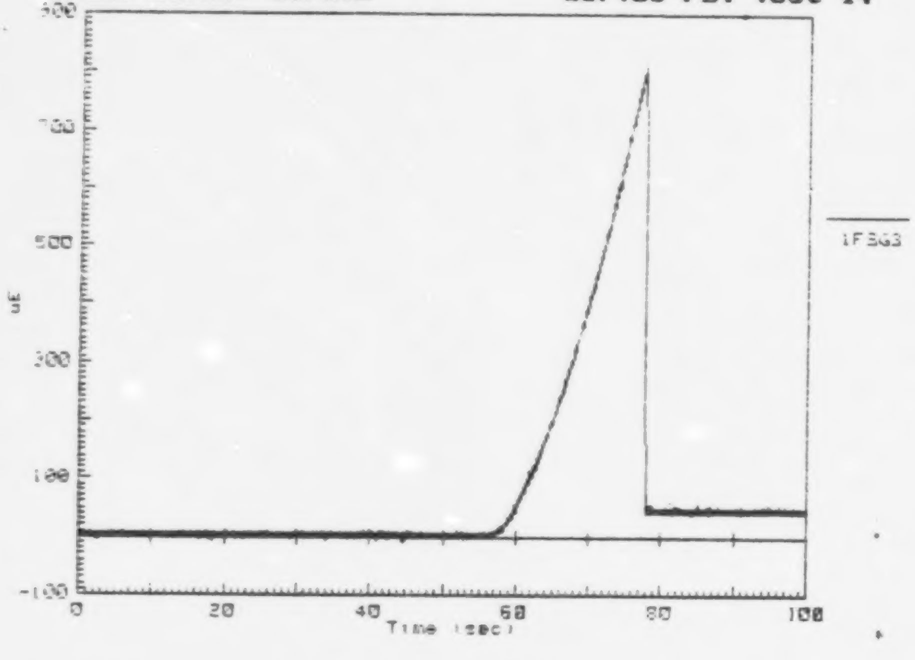
GEOTECHnical Resources Ltd.   ANALYSIS DATE:19 May 1988

Blade Single-Axis Strain   **Series PBT Test 14**



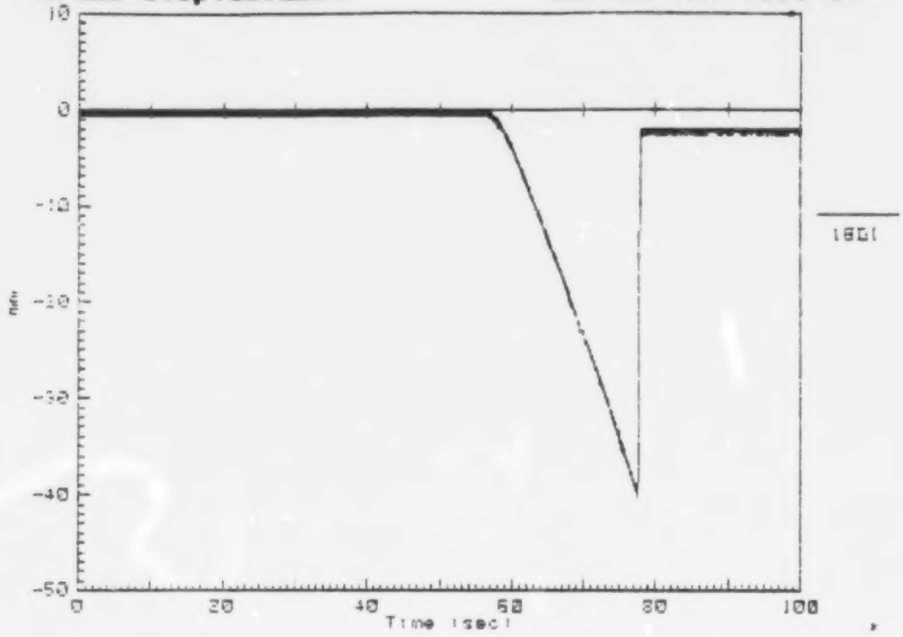
GEOTECHnical Resources Ltd.   ANALYSIS DATE:19 May 1988

Frame Girder Strain   **Series PBT Test 14**



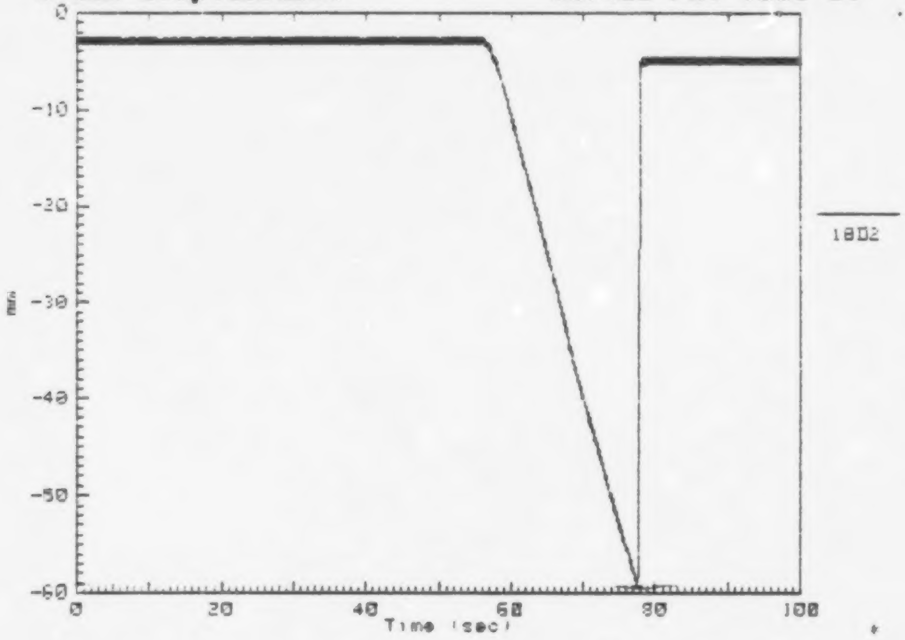
GEOTECHnical Resources Ltd. ANALYSIS DATE:19 May 1988

Blade Displacement **Series PBT Test 14**



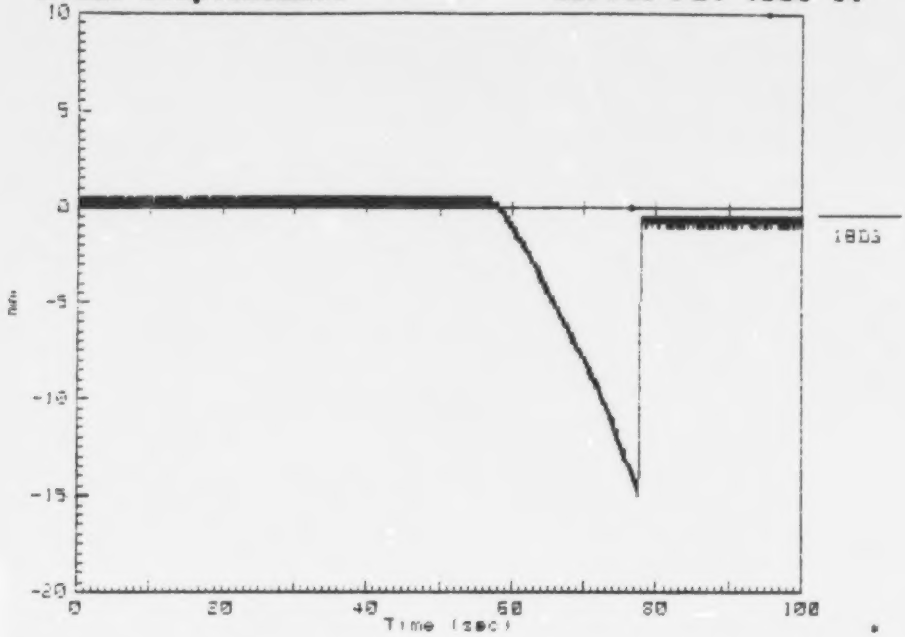
GEOTECHnical Resources Ltd. ANALYSIS DATE:19 May 1988

Blade Displacement **Series PBT Test 14**



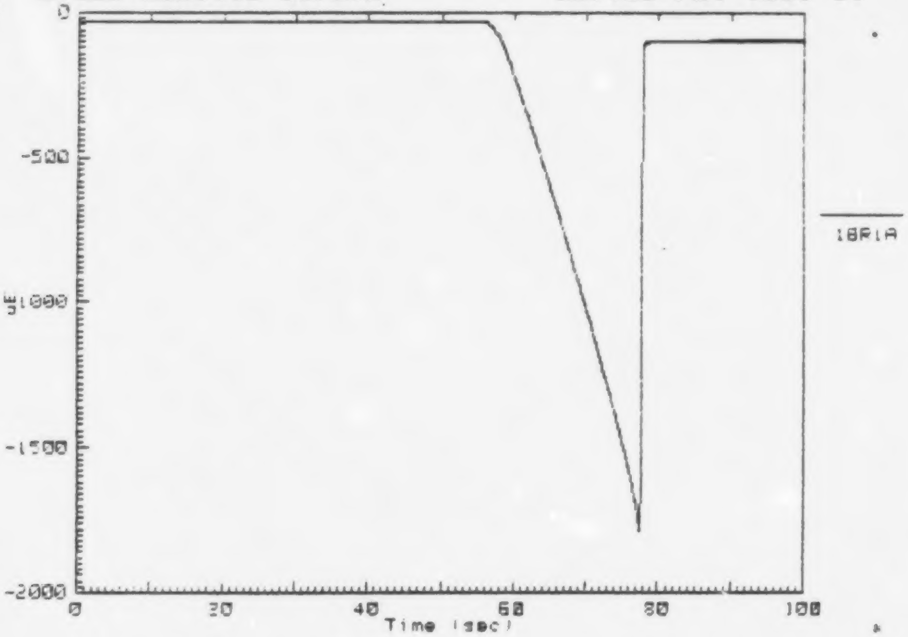
GEOTECHnical Resources Ltd. ANALYSIS DATE: 19 May 1988

Blade Displacement **Series PBT Test 14**



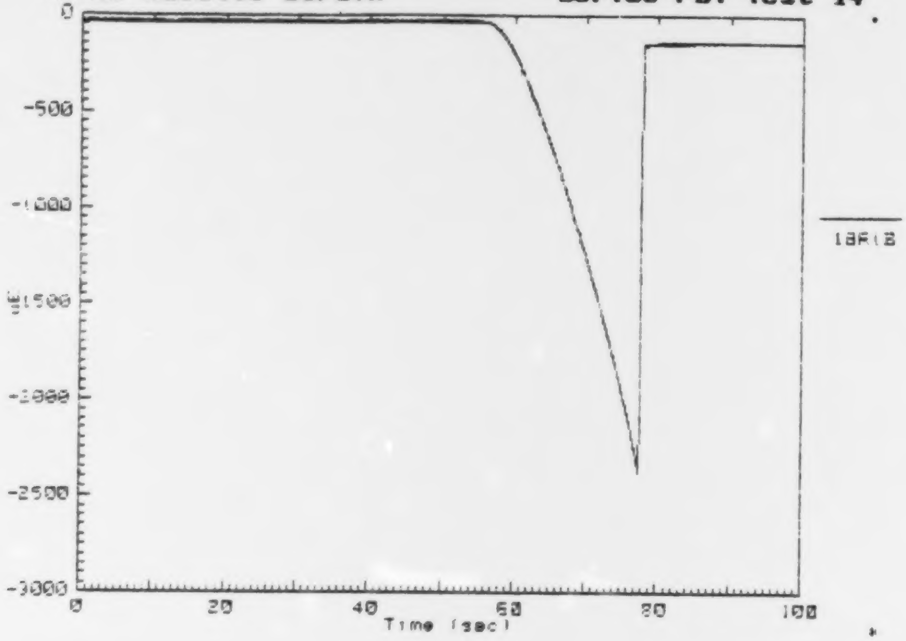
GEOTECHnical Resources Ltd. ANALYSIS DATE: 19 May 1988

Blade Rosette Strain **Series PBT Test 14**



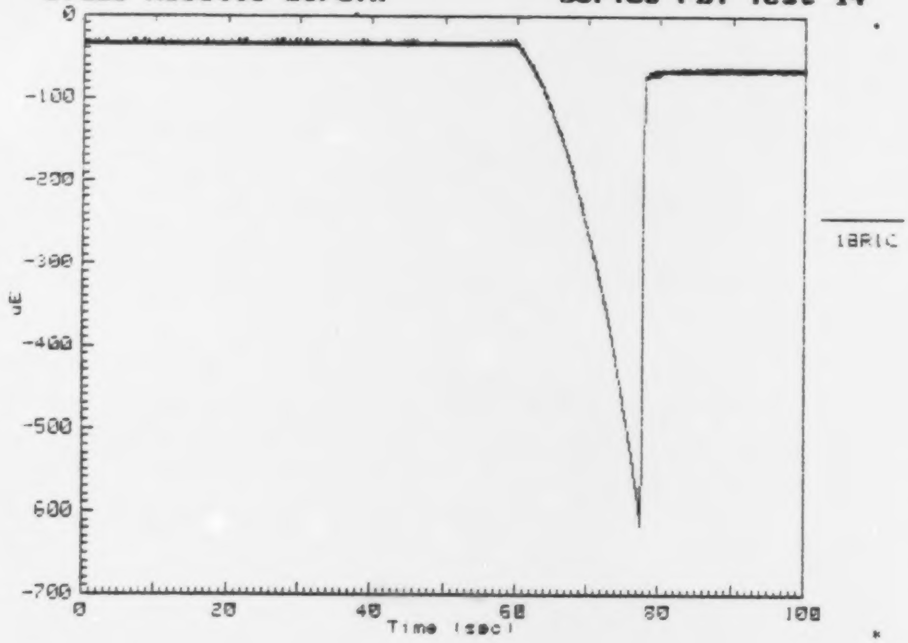
GEOTECHnical Resources Ltd. ANALYSIS DATE:19 May 1988

Blade Rosette Strain **Series PBT Test 14**



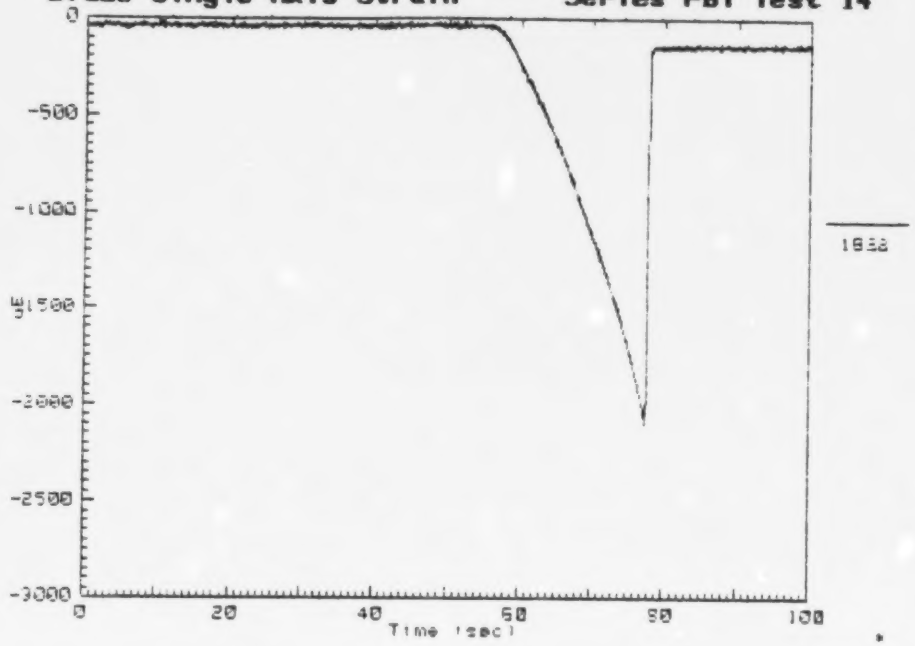
GEOTECHnical Resources Ltd. ANALYSIS DATE:19 May 1988

Blade Rosette Strain **Series PBT Test 14**



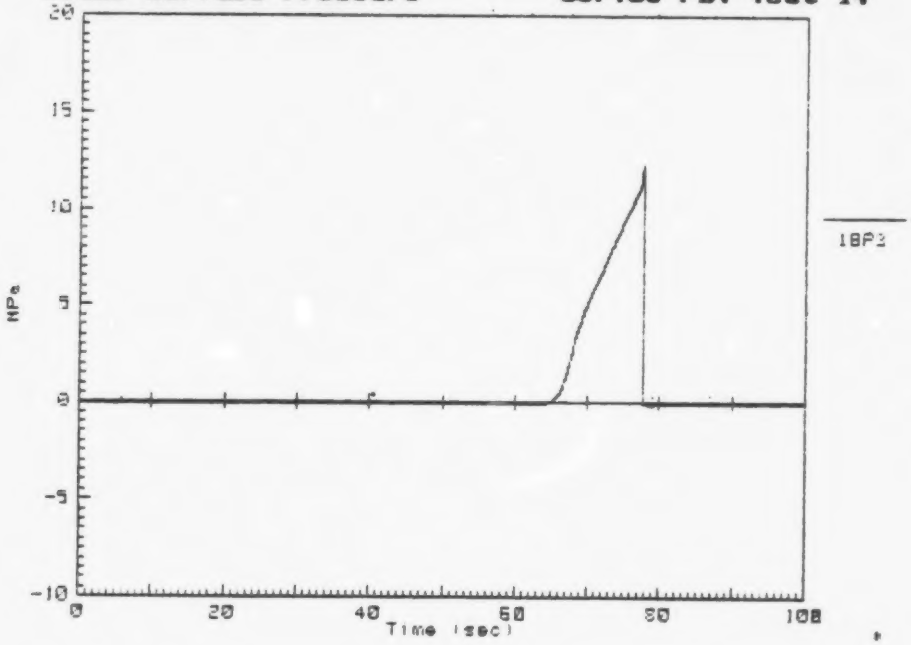
GEOTECHnical Resources Ltd. ANALYSIS DATE: 19 May 1988

Blade Single-Axis Strain **Series PBT Test 14**



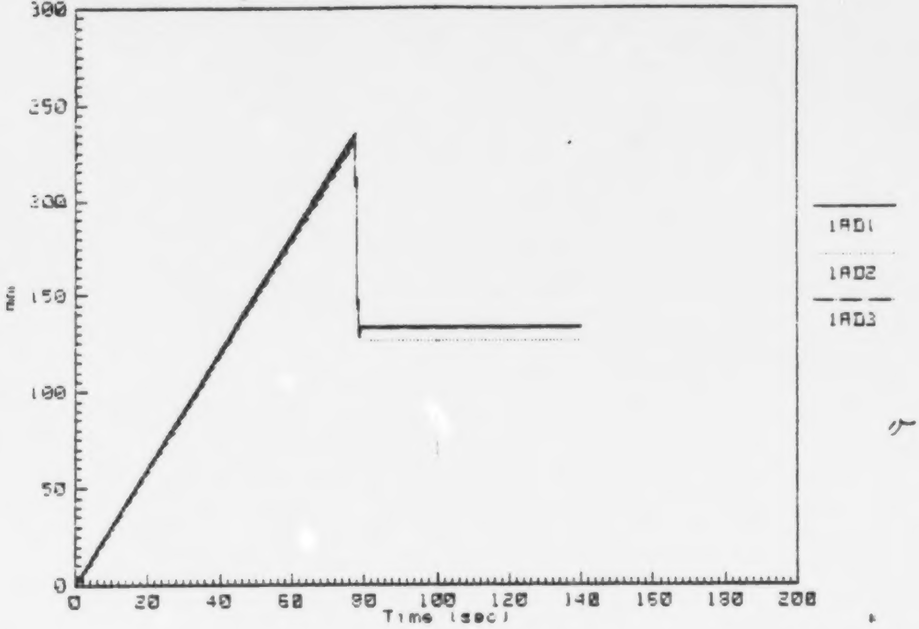
GEOTECHnical Resources Ltd. ANALYSIS DATE: 19 May 1988

Blade Surface Pressure **Series PBT Test 14**



GEOTECHnical Resources Ltd.   ANALYSIS DATE: 8 Jul 1988

Actuator Displacement   **Series PBT Test 14**



$$v = \frac{300\ mm}{100\ s}$$

$$= 3\ mm/s$$

```
                    GEOTECHnical resources ltd
                           PROP BUSTERS
                       PROJECT NUMBER: 9448


Date: 19 May 1988
Time: 15:00:33

Test series...... PBT
Test number...... 15

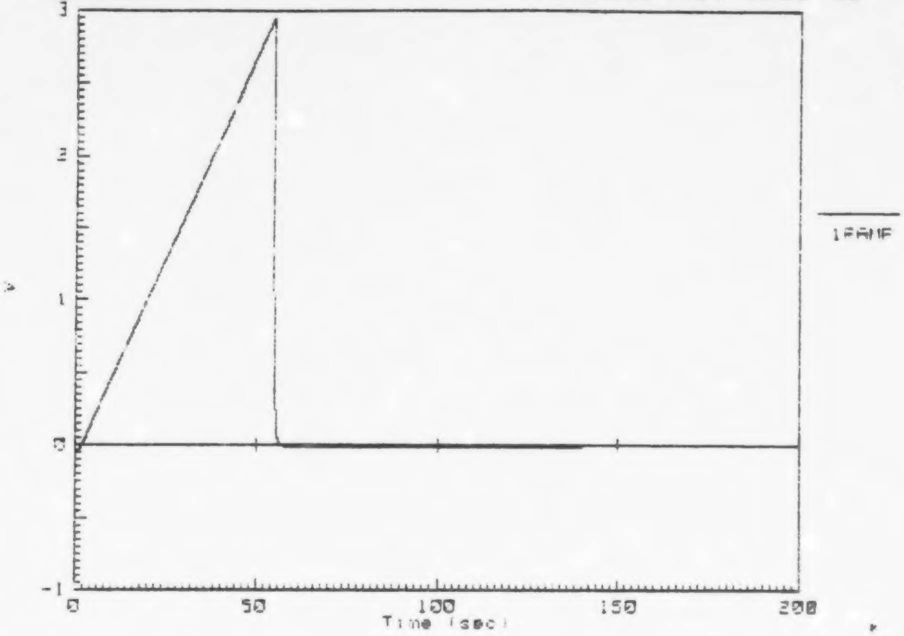
*** Window 1 ***
Test duration .................. 140 Second(s)
AD-200 sample period............ 277.75 Micro-second(s)
Sample rate, aggregate ......... 3600 Hz.
Sample rate per channel ........ 225 Hz.
Number of samples per channel .. 31504 words.
Total number of samples ........ 1.008128E+6 words.
Trigger source ................. INTERNAL
Number of cards ................ 2
Number of channels per card .... 16
Total number of channels ....... 32
```

Transducer table for test #PBT15_HDR

```
14750 Card1:!
14750    |-----|--|--|--|--|----|---------|---------|--------|------|----------|
14770    |Card |Ch|SW|HW|Ex|Mode|  Gain   | Offset  | Units  |  Ch  |  Serial  |
14780    | no. |no|gn|gn|gn|    | (eng/V)|   (V)   |  (/V)  |  Id  |  Number  |
14790    |-----|--|--|--|--|----|---------|---------|--------|------|----------|
14800   DATA 1, 1, 1, 1, 1, "S",  107.29,  2.7124,    "mm", "BD1",   "A33380"
14810   DATA 1, 2, 1, 1, 1, "S",  107.42,  2.0726,    "mm", "BD2",   "A22090"
14820   DATA 1, 3, 1, 1, 1, "S",  107.42,  2.3608,    "mm", "BD3",   "A22091"
14830   DATA 1, 4, 1, 1, 1, "S",  6.8529,  0.0879,   "MPa","APR1",     "5817"
14840   DATA 1, 5, 1, 1, 1, "S",  6.8586,  0.0049,   "MPa","APE1",     "4996"
14850   DATA 1, 6, 1, 1, 1, "S",  6.9792,  0.0562,   "MPa","APR2",     "5723"
14860   DATA 1, 7, 1, 1, 1, "S",  6.8636,  0.0708,   "MPa","APE2",     "5815"
14870   DATA 1, 8, 1, 1, 1, "S",  6.8643,  0.0806,   "MPa","APR3",     "5863"
14880   DATA 1, 9, 1, 1, 1, "S",  6.8531,  0.0562,   "MPa","APE3",     "5885"
14890   DATA 1,10, 1, 1, 1, "S",  13.709,  0.0757,   "MPa", "BP1",     "5887"
14900   DATA 1,11, 1, 1, 1, "S",  13.712,  0.1025,   "MPa", "BP2",     "5773"
14910   DATA 1,12, 1, 1, 1, "S",  13.734,  0.0806,   "MPa", "BP3",     "5892"
14920   DATA 1,13, 1, 1, 1, "S",  13.731,  0.0708,   "MPa", "BP4",     "5889"
14930   DATA 1,14, 1, 1, 1, "S",  13.717,  0.0635,   "MPa", "BP5",     "5891"
14940   DATA 1,15, 1, 1, 2, "S",     1.0,       0,   "  V","RAMP",     "    "
14950   DATA 1,16, 1, 1, 1, "S",  1000.0,       0,    "uE","BR1B",     "    "
14960 Card2:!
14970   DATA 2, 1 ,1, 1, 2, "S",  53.906,  1.3525,    "mm", "AD1",   "A22091"
14980   DATA 2, 2, 1, 1, 2, "S",  53.634,  1.3379,    "mm", "AD2",   "A33381"
14990   DATA 2, 3, 1, 1, 2, "S",  53.608,  1.4599,    "mm", "AD3",   "A33382"
15000   DATA 2, 4, 1, 1, 1, "S",  1000.0,       0,    "uE","BR1A",     "    "
15010   DATA 2, 5, 1, 1, 1, "S",  1000.0,       0,    "uE","BR2A",     "    "
15020   DATA 2, 6, 1, 1, 1, "S",  1000.0,       0,    "uE","FSG3",     "    "
15030   DATA 2, 7, 1, 1, 1, "S",  1000.0,       0,    "uE", "BS7",     "    "
15040   DATA 2, 8, 1, 1, 1, "S",  1000.0,       0,    "uE", "BS8",     "    "
15050   DATA 2, 9, 1, 1, 1, "S",  1000.0,       0,    "uE", "BS9",     "    "
15060   DATA 2,10, 1, 1, 1, "S",  1000.0,       0,    "uE", "BS1",     "    "
15070   DATA 2,11, 1, 1, 1, "S",  1000.0,       0,    "uE","BR2B",     "    "
15080   DATA 2,12, 1, 1, 1, "S",  1000.0,       0,    "uE", "BS3",     "    "
15090   DATA 2,13, 1, 1, 1, "S",  1000.0,       0,    "uE", "BS4",     "    "
15100   DATA 2,14, 1, 1, 1, "S",  1000.0,       0,    "uE", "BS2",     "    "
15110   DATA 2,15, 1, 1, 1, "S",  1000.0,  0.2881,    "uE","BR2C",     "    "
15120   DATA 2,16, 1, 1, 1, "S",  1000.0,       0,    "uE","BR1C",     "    "
15130    |-----|--|--|--|--|----|---------|---------|--------|------|----------|
15140    |Card |Ch|SW|HW|Ex|Mode|  Gain   | Offset  | Units  |  Ch  |  Serial  |
15150    | no. |no|gn|gn|gn|    | (Eng/V)|   (V)   |  (/V)  |  Id  |  Number  |
15160    |-----|--|--|--|--|----|---------|---------|--------|------|----------|
15170 End_transducers:!
```

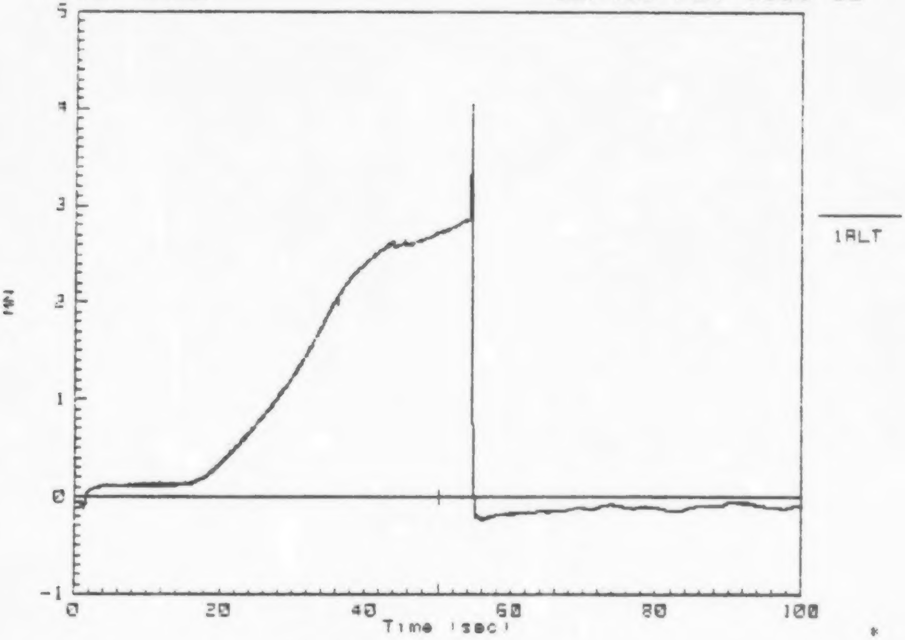
GEOTECHnical Resources Ltd. ANALYSIS DATE:19 May 1988

Command **Series PBT Test 15**



GEOTECHnical Resources Ltd. ANALYSIS DATE:19 May 1988

Total Load **Series PBT Test 15**



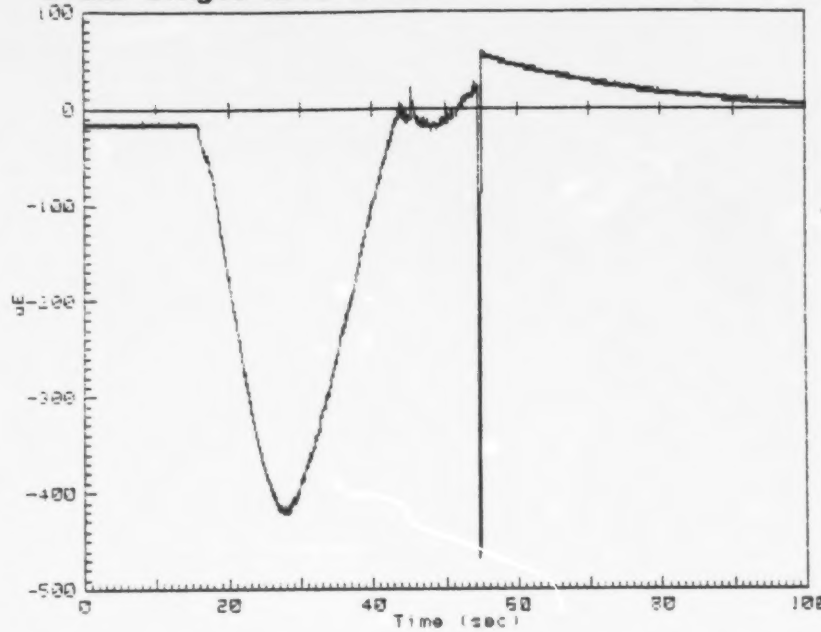
[illegible]

[illegible] MN

@ [illegible]

GEOTECHnical Resources Ltd.   ANALYSIS DATE: 19 May 1986

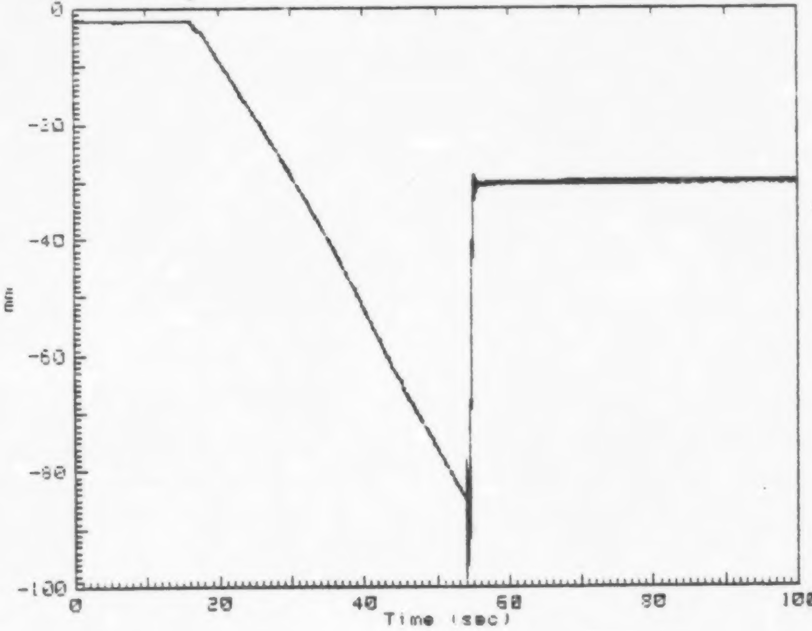
Blade Single-Axis Strain   Series PBT Test 15



1851

GEOTECHnical Resources Ltd.   ANALYSIS DATE: 19 May 1986

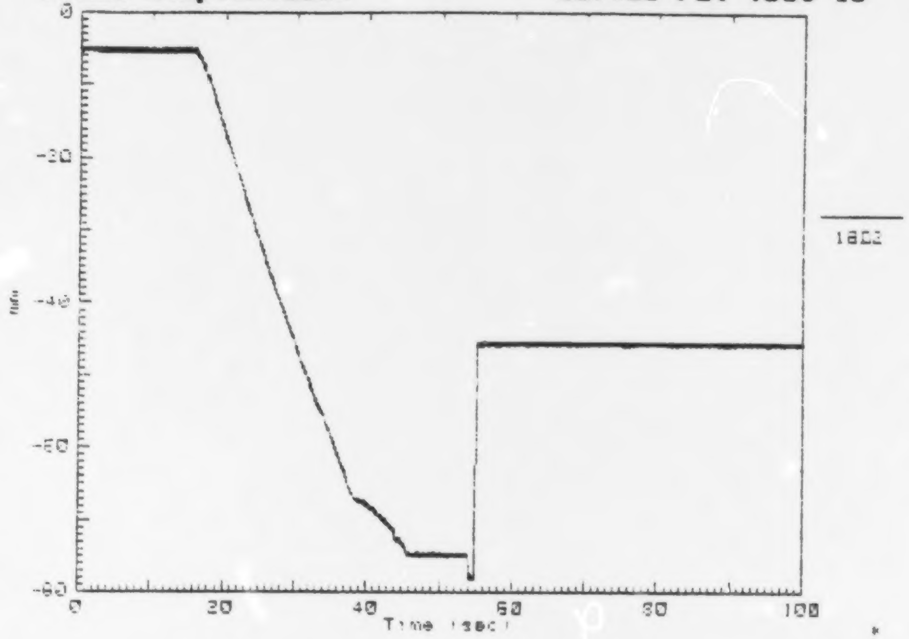
Blade Displacement   Series PBT Test 15



1801

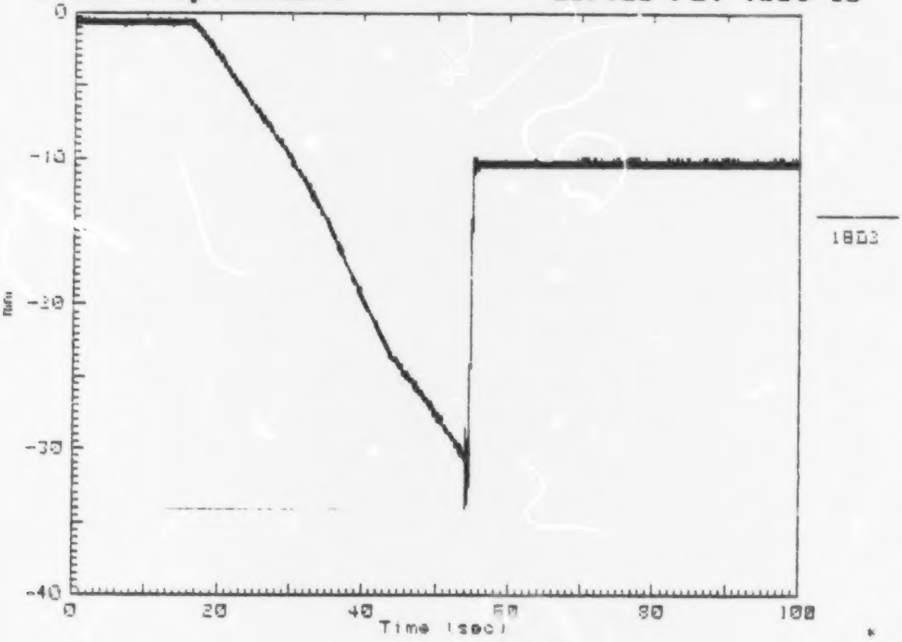
GEOTECHnical Resources Ltd. ANALYSIS DATE:19 May 1988

Blade Displacement **Series PBT Test 15**



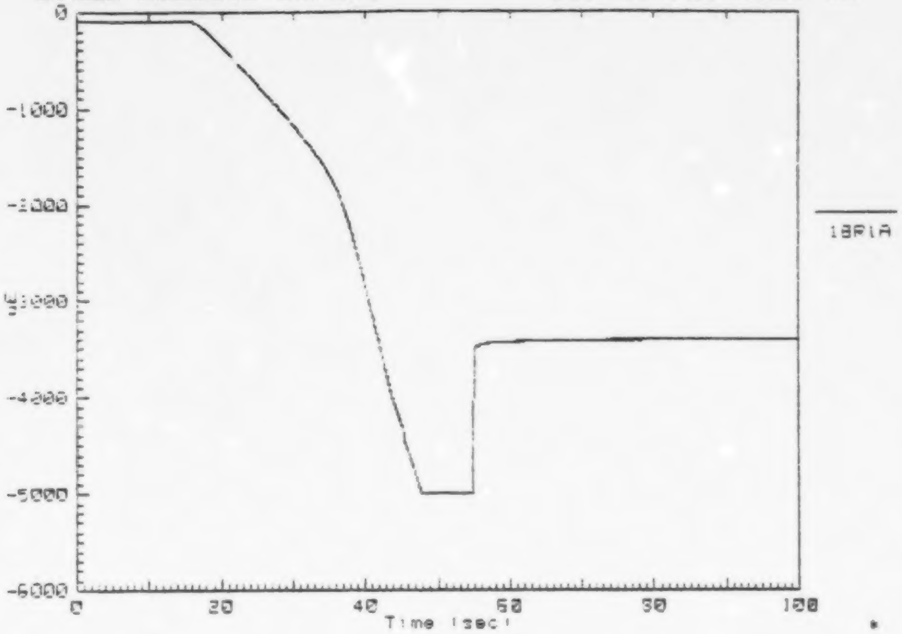
GEOTECHnical Resources Ltd. ANALYSIS DATE:19 May 1988

Blade Displacement **Series PBT Test 15**



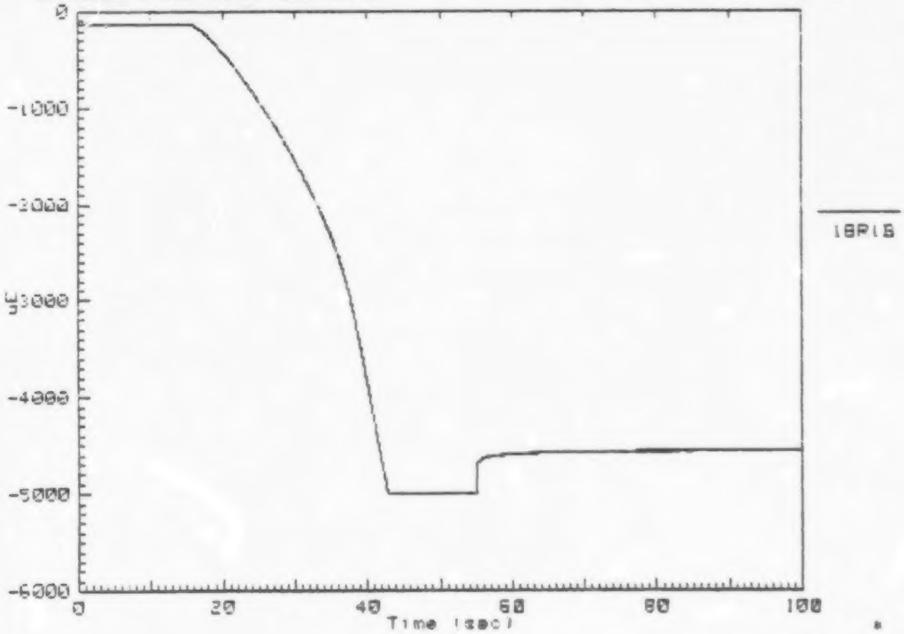
GEOTECHnical Resources Ltd.   ANALYSIS DATE:19 May 1988

Blade Rosette Strain   **Series PBT Test 15**



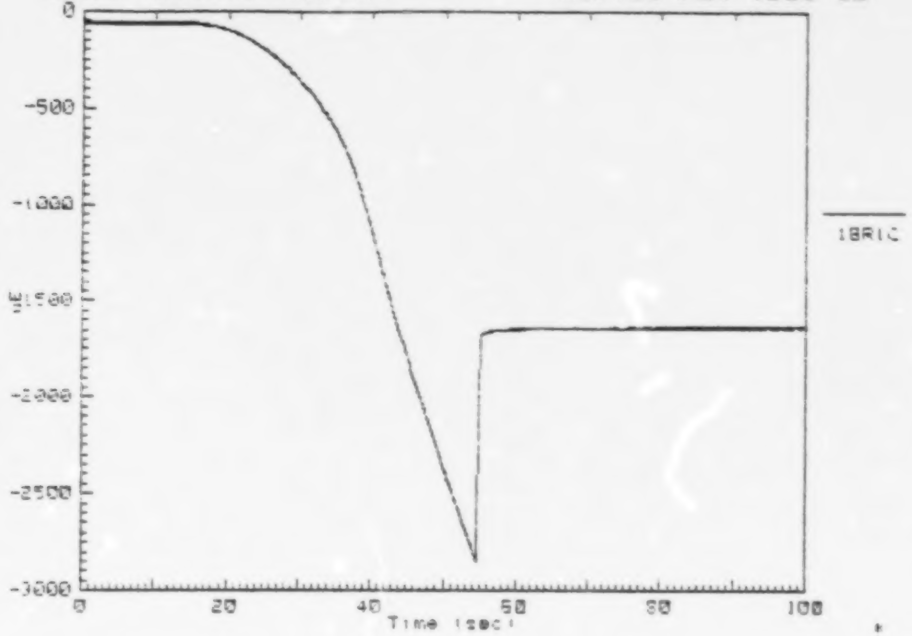
GEOTECHnical Resources Ltd.   ANALYSIS DATE:19 May 1988

Blade Rosette Strain   **Series PBT Test 15**



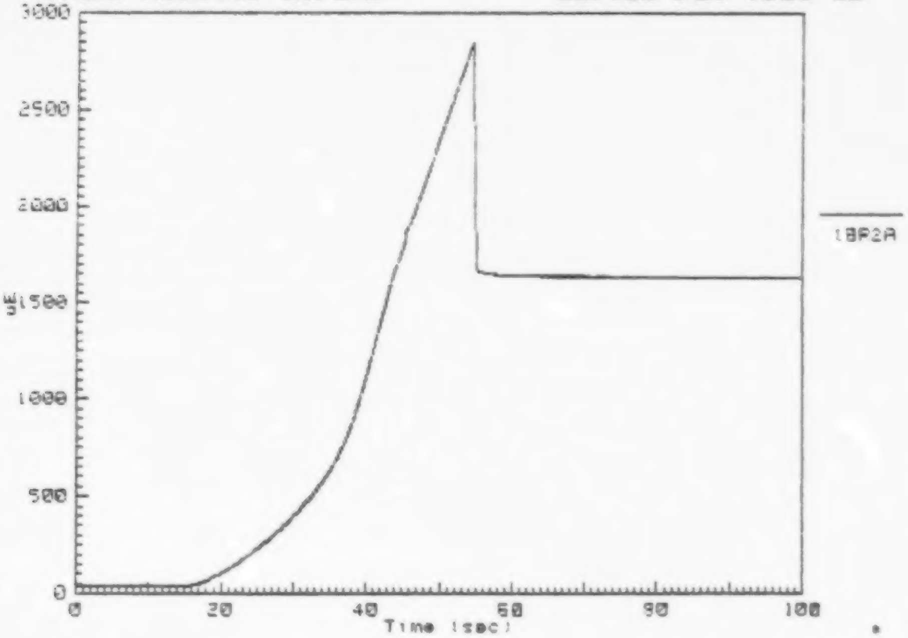
GEOTECHnical Resources Ltd. ANALYSIS DATE:19 May 1988

Blade Rosette Strain **Series PBT Test 15**



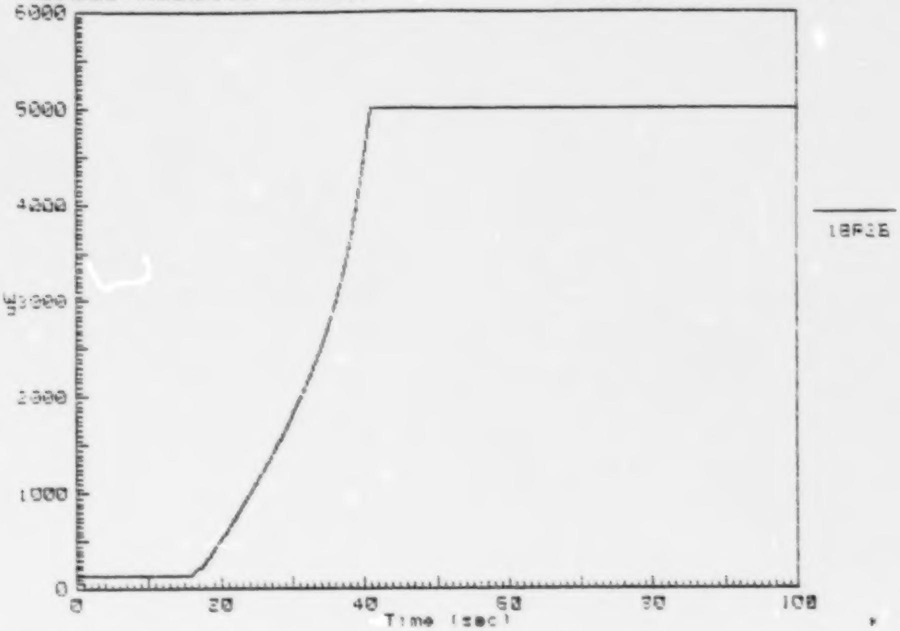
GEOTECHnical Resources Ltd. ANALYSIS DATE:19 May 1988

Blade Rosette Strain **Series PBT Test 15**



GEOTECHnical Resources Ltd. ANALYSIS DATE:19 May 1988

Blade Rosette Strain **Series PBT Test 15**

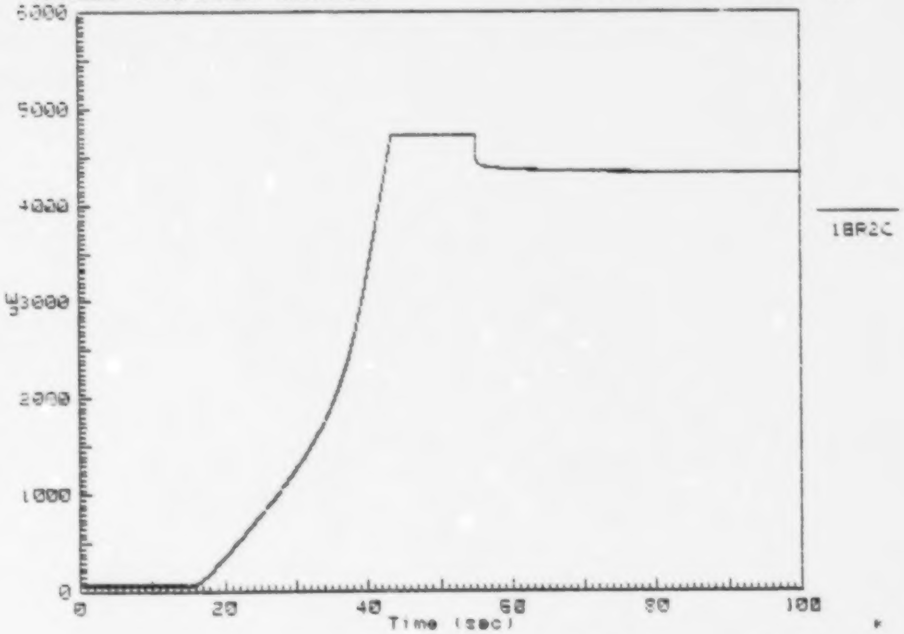


5.875 × 1000 =

5875 με

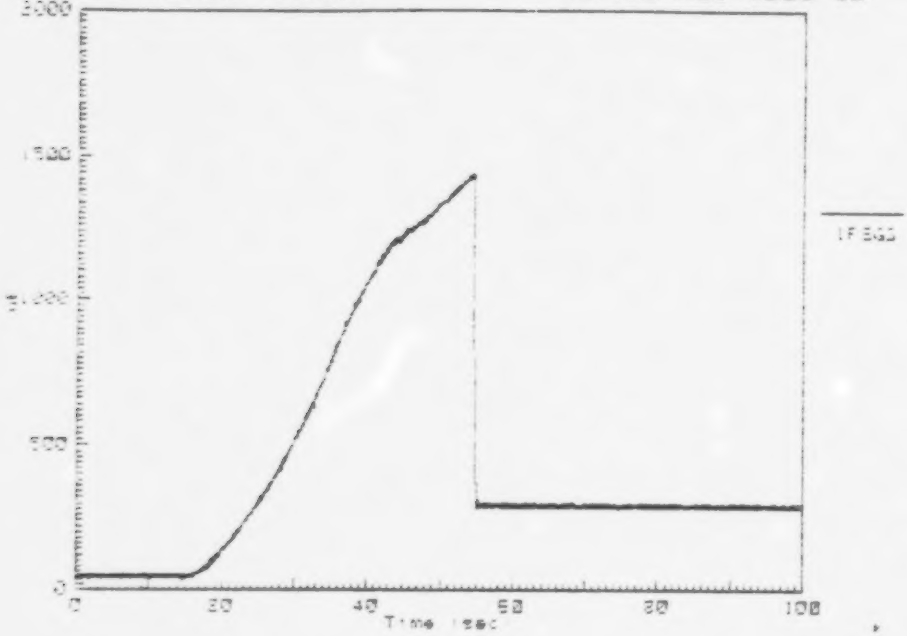
GEOTECHnical Resources Ltd. ANALYSIS DATE:19 May 1988

Blade Rosette Strain **Series PBT Test 15**



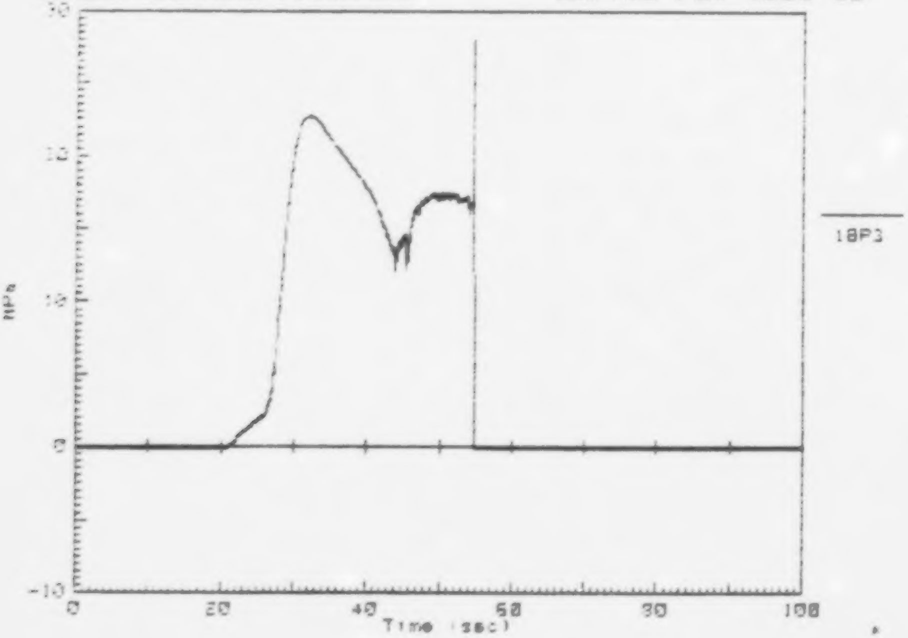
GEOTEChnical Resources Ltd. ANALYSIS DATE:19 May 1988

Frame Girder Strain **Series PBT Test 15**



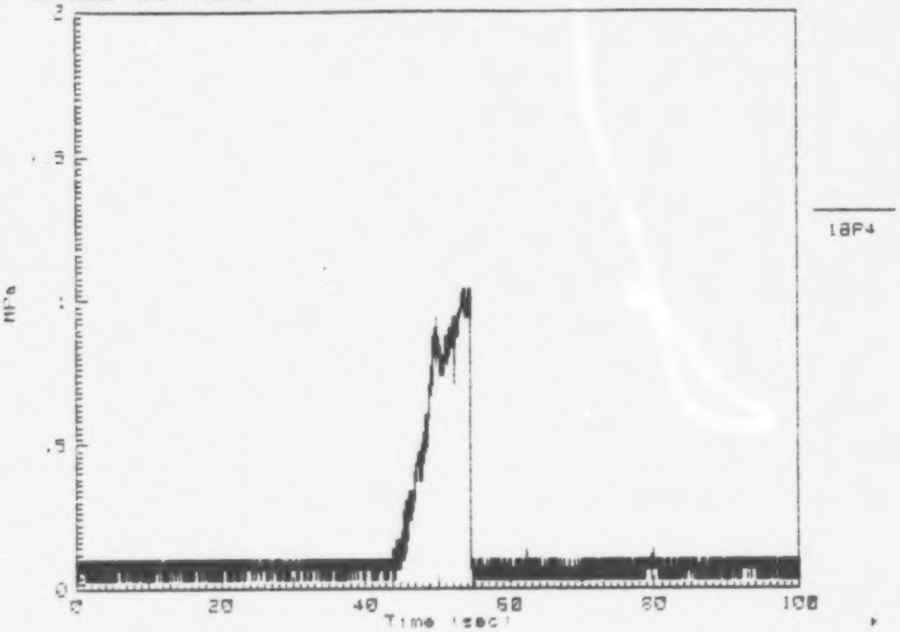
GEOTEChnical Resources Ltd. ANALYSIS DATE:19 May 1988

Blade Surface Pressure **Series PBT Test 15**



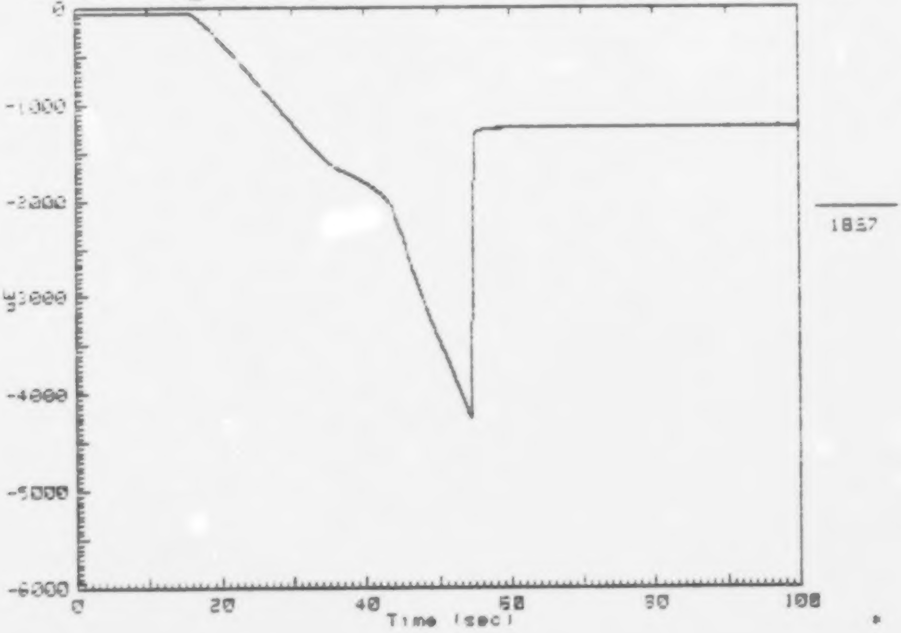
GEOTECHnical Resources Ltd. ANALYSIS DATE:19 May 1988

Blade Surface Pressure **Series PBT Test 15**



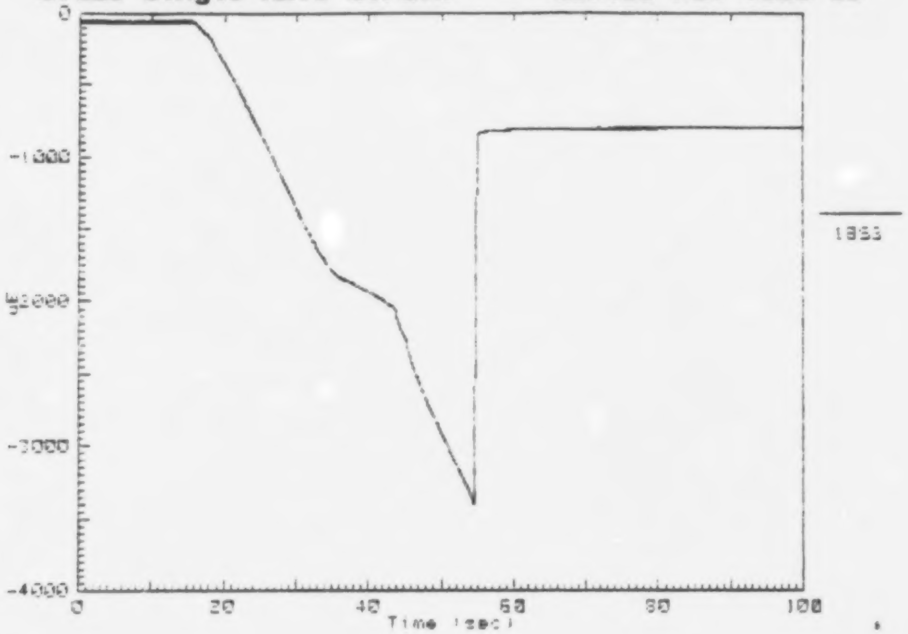
GEOTECHnical Resources Ltd. ANALYSIS DATE:19 May 1988

Blade Single-Axis Strain **Series PBT Test 15**



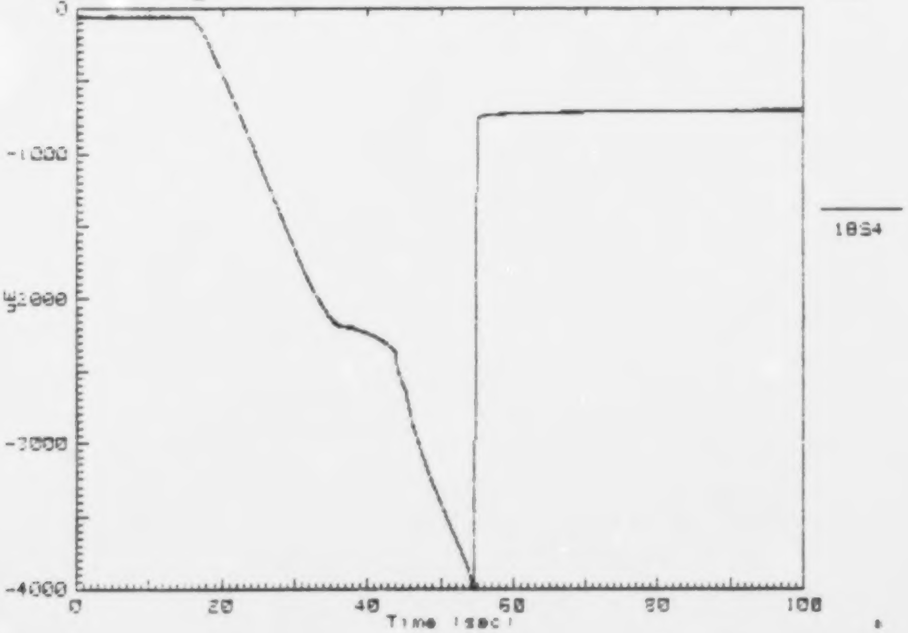
GEOTECHnical Resources Ltd. ANALYSIS DATE:19 May 1988

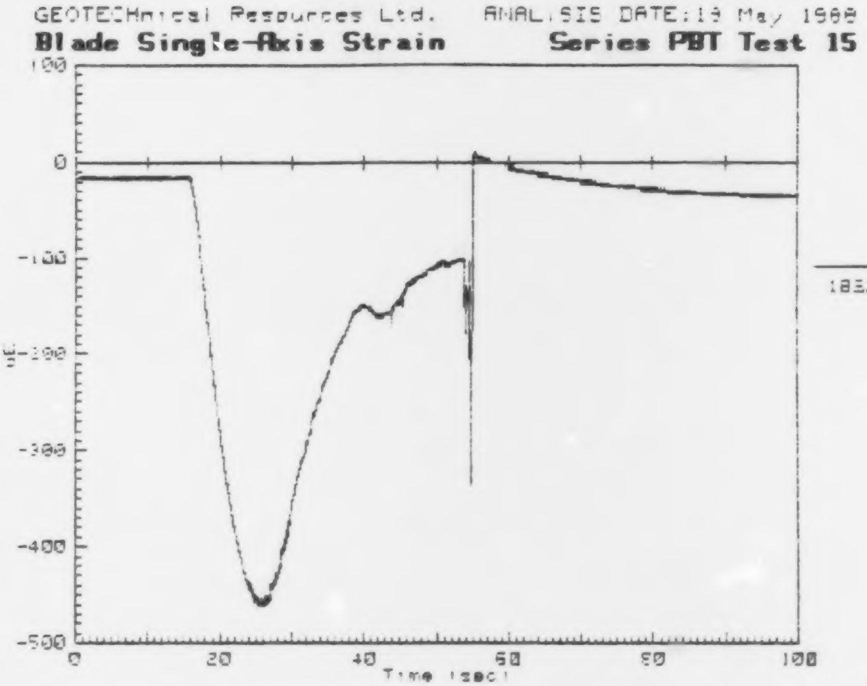
Blade Single-Axis Strain **Series PBT Test 15**



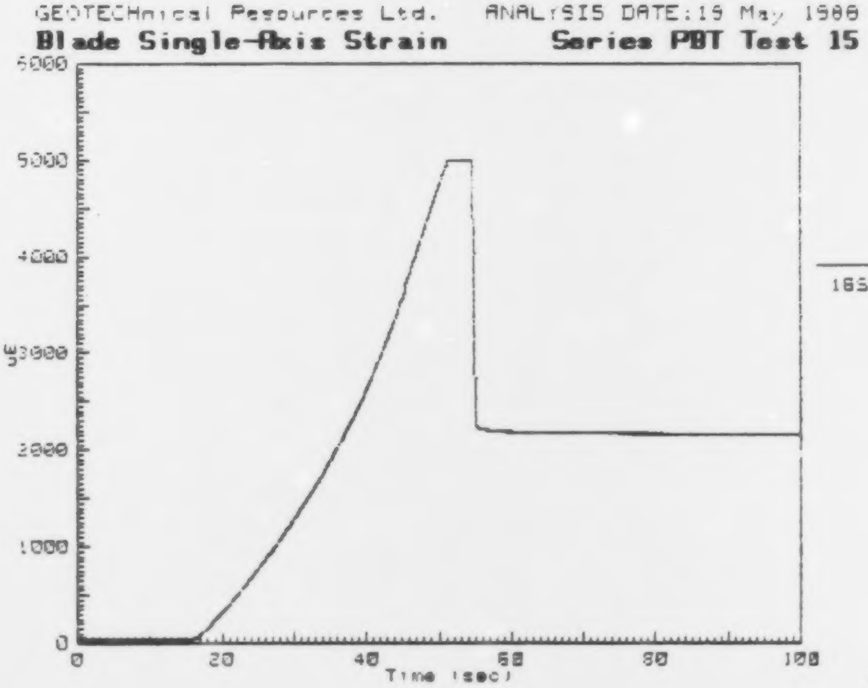
GEOTECHnical Resources Ltd. ANALYSIS DATE:19 May 1988

Blade Single-Axis Strain **Series PBT Test 15**




GEOTECHnical Resources Ltd. ANALYSIS DATE:19 May 1988
Blade Single-Axis Strain
Series PBT Test 15
100
0
-100
-200
-300
-400
-500
με
0
20
40
60
80
100
Time (sec)

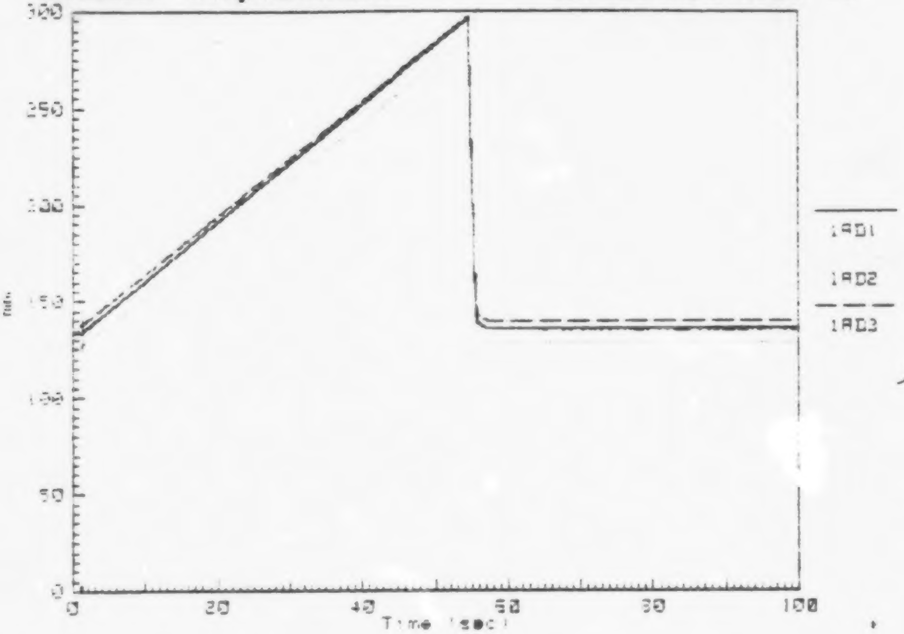
1852


GEOTECHnical Resources Ltd. ANALYSIS DATE:19 May 1988
Blade Single-Axis Strain
Series PBT Test 15
6000
5000
4000
3000
2000
1000
0
με
0
20
40
60
80
100
Time (sec)

1853

GEOTECHnical Resources Ltd. ANALYSIS DATE:19 May 1988

Actuator Displacement **Series PBT Test 15**

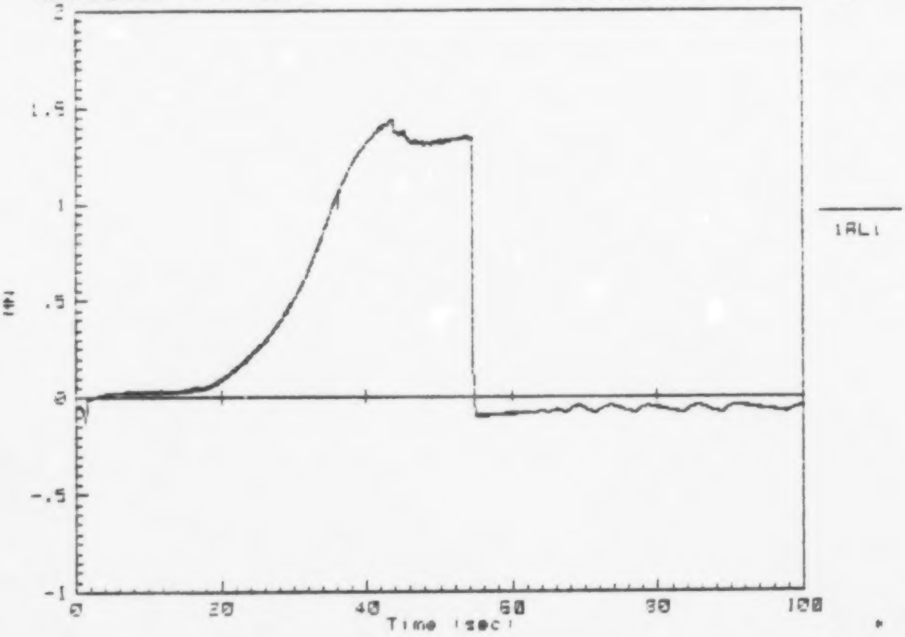


$v \doteq \frac{300\ mm}{56 \cdot [illegible]}$

$\doteq 5.45\ \frac{mm}{s}$

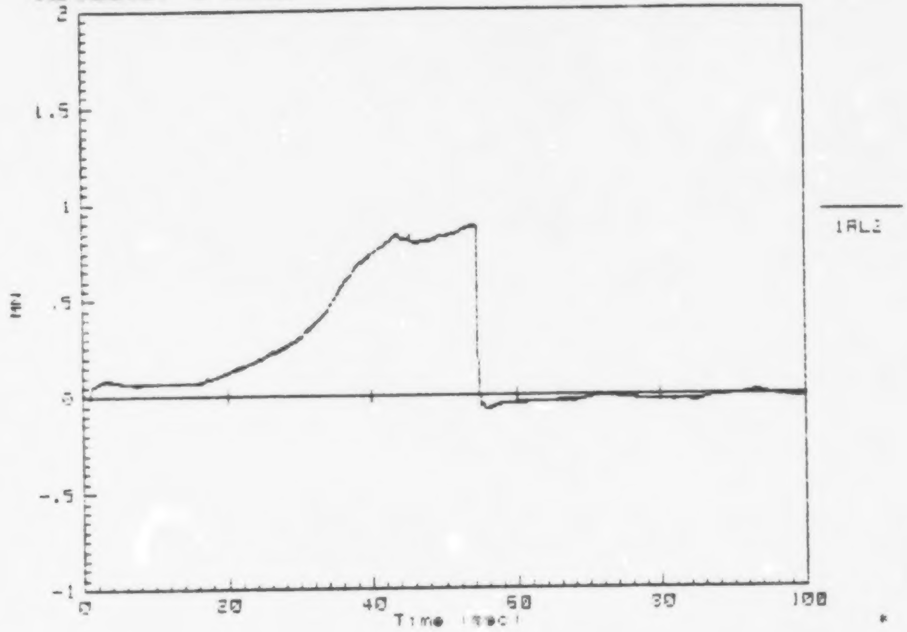
GEOTECHnical Resources Ltd. ANALYSIS DATE:19 May 1988

Actuator 1 Load **Series PBT Test 15**



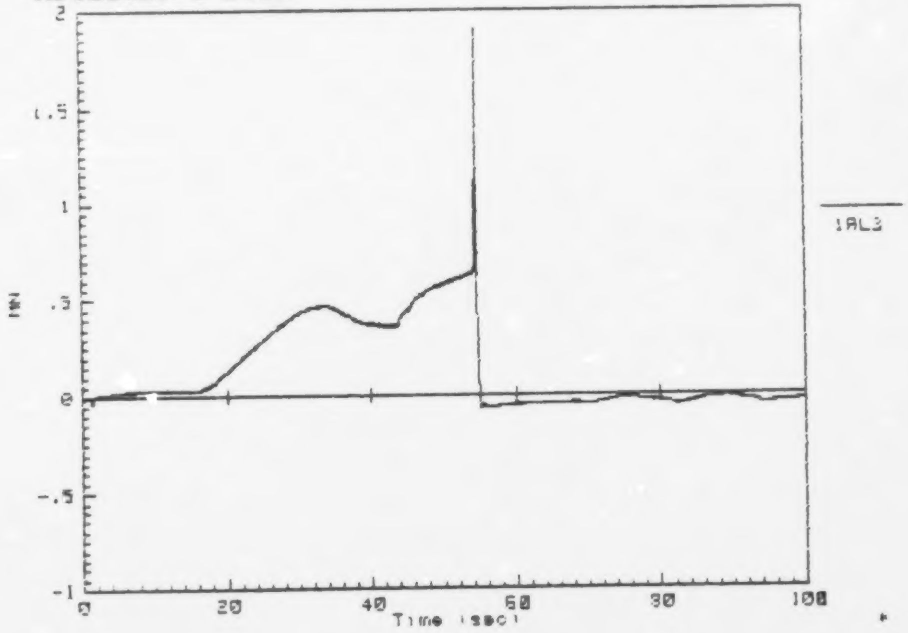
GEOTECHnical Resources Ltd. ANALYSIS DATE: 19 May 1988

Actuator 2 Load **Series PBT Test 15**



GEOTECHnical Resources Ltd. ANALYSIS DATE: 19 May 1988

Actuator 3 Load **Series PBT Test 15**

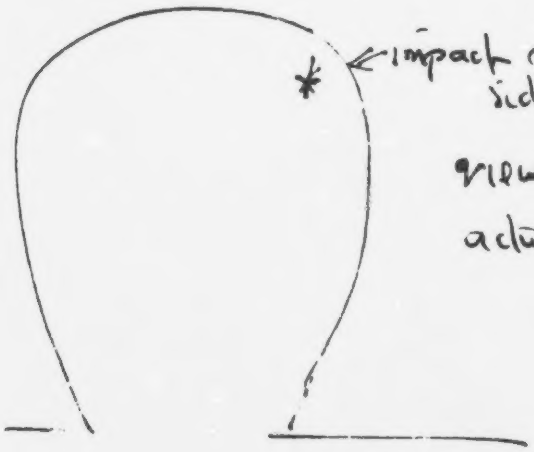


GEOTECHnical resources ltd
PROP BUSTERS
PROJECT NUMBER: 9448

```
Date: 20 May 1988
Time: 11:29:00

Test series...... PBT
Test number...... 16

*** Window 1 ***
Test duration .................... 6 Second(s)
AD-200 sample period.............. 16.1 Micro-second(s)
Sample rate, aggregate ........... 62111 Hz.
Sample rate per channel .......... 3881 Hz.
Number of samples per channel .. 23292 words.
Total number of samples .......... 745344 words.
Trigger source ................... INTERNAL
Number of cards .................. 2
Number of channels per card .... 16
Total number of channels ........ 32
```



impact point on actuator side of blade

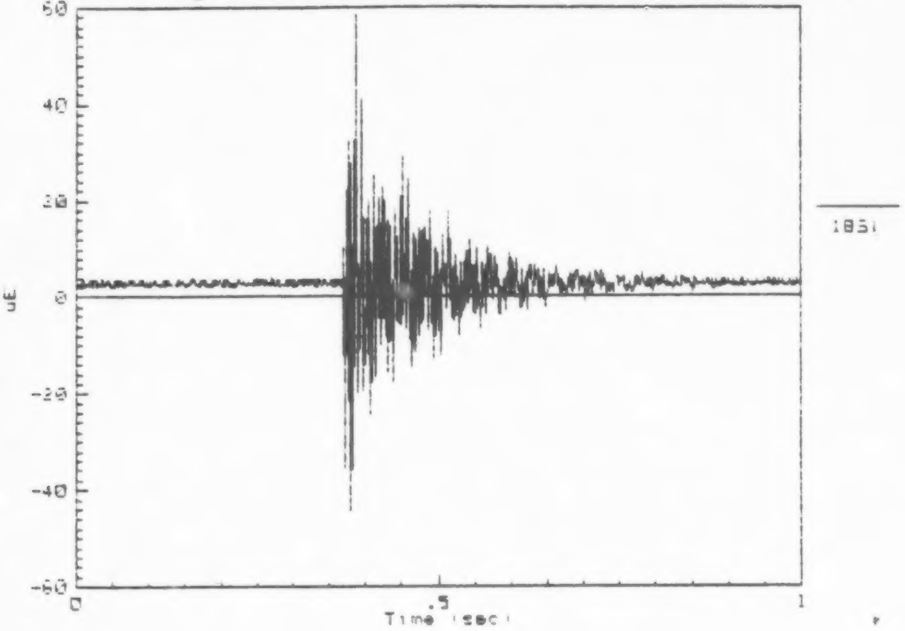
view <u>from</u> actuator side

Transducer table for test #FBT16_HDP

```
14750 Card1:!
14760   !-----|--|--|--|--|----|---------|---------|--------|------|----------|
14770   !Card |Ch|SW|HW|E-|Mode|  Gain   | Offset  | Units  |  Ch  |  Serial  |
14780   ! no. |no|gn|gn|gn|    | (eng/V) |   (V)   |  (/V)  |  Id  |  Number  |
14790   !-----|--|--|--|--|----|---------|---------|--------|------|----------|
14800   DATA 1, 1, 1, 1, 1, "S",  107.29,  2.7124,    "mm", "BD1",  "A33380"
14810   DATA 1, 2, 1, 1, 1, "S",  107.42,  2.0726,    "mm", "BD2",  "A22090"
14820   DATA 1, 3, 1, 1, 1, "S",  107.42,  2.3608,    "mm", "BD3",  "A22091"
14830   DATA 1, 4, 1, 1, 1, "S",  6.8529,  0.0879,   "MPa","APR1",    "5817"
14840   DATA 1, 5, 1, 1, 1, "S",  6.8586,  0.0049,   "MPa","APE1",    "4986"
14850   DATA 1, 6, 1, 1, 1, "S",  6.8792,  0.0562,   "MPa","APR2",    "5723"
14860   DATA 1, 7, 1, 1, 1, "S",  6.8636,  0.0708,   "MPa","APE2",    "5815"
14870   DATA 1, 8, 1, 1, 1, "S",  6.8643,  0.0806,   "MPa","APR3",    "5883"
14880   DATA 1, 9, 1, 1, 1, "S",  6.8531,  0.0562,   "MPa","APE3",    "5895"
14890   DATA 1,10, 1, 1, 1, "S",  13.709,  0.0757,   "MPa", "BP1",    "5887"
14900   DATA 1,11, 1, 1, 1, "S",  13.712,  0.1025,   "MPa", "BP2",    "5773"
14910   DATA 1,12, 1, 1, 1, "S",  13.734,  0.0806,   "MPa", "BP3",    "5892"
14920   DATA 1,13, 1, 1, 1, "S",  13.731,  0.0708,   "MPa", "BP4",    "5889"
14930   DATA 1,14, 1, 1, 1, "S",  13.717,  0.0635,   "MPa", "BP5",    "5891"
14940   DATA 1,15, 1, 1, 2, "S",     1.0,       0,   "  V","RAMP",    "    "
14950   DATA 1,16, 5, 1, 1, "S",  1000.0,       0,    "uE","BR1B",    "    "
14960 Card2:!
14970   DATA 2, 1 ,1, 1, 2, "S",  53.906,  1.3525,    "mm", "AD1",  "A22091"
14980   DATA 2, 2, 1, 1, 2, "S",  53.634,  1.3379,    "mm", "AD2",  "A33381"
14990   DATA 2, 3, 1, 1, 2, "S",  53.608,  1.4599,    "mm", "AD3",  "A33382"
15000   DATA 2, 4, 5, 1, 1, "S",  1000.0,       0,    "uE","BR1A",  "      "
15010   DATA 2, 5, 5, 1, 1, "S",  1000.0,       0,    "uE","BR2A",  "      "
15020   DATA 2, 6, 1, 1, 1, "S",  1000.0,       0,    "uE","FSG3",  "      "
15030   DATA 2, 7, 5, 1, 1, "S",  1000.0,       0,    "uE", "BS7",  "      "
15040   DATA 2, 8, 5, 1, 1, "S",  1000.0,       0,    "uE", "BS8",  "      "
15050   DATA 2, 9, 5, 1, 1, "S",  1000.0,       0,    "uE", "BS9",  "      "
15060   DATA 2,10, 5, 1, 1, "S",  1000.0,       0,    "uE", "BS1",  "      "
15070   DATA 2,11, 5, 1, 1, "S",  1000.0,       0,    "uE","BR2B",  "      "
15080   DATA 2,12, 5, 1, 1, "S",  1000.0,       0,    "uE", "BS3",  "      "
15090   DATA 2,13, 5, 1, 1, "S",  1000.0,       0,    "uE", "BS4",  "      "
15100   DATA 2,14, 5, 1, 1, "S",  1000.0,       0,    "uE", "BS2",  "      "
15110   DATA 2,15, 5, 1, 1, "S",  1000.0,  0.2881,    "uE","BR2C",  "      "
15120   DATA 2,16, 5, 1, 1, "S",  1000.0,       0,    "uE","BR1C",  "      "
15130   !-----|--|--|--|--|----|---------|---------|--------|------|----------|
15140   !Card |Ch|SW|HW|Ex|Mode|  Gain   | Offset  | Units  |  Ch  |  Serial  |
15150   ! no. |no|gn|gn|gn|    | (Eng/V) |   (V)   |  (/V)  |  Id  |  Number  |
15160   !-----|--|--|--|--|----|---------|---------|--------|------|----------|
15170 End_transducers:!
```

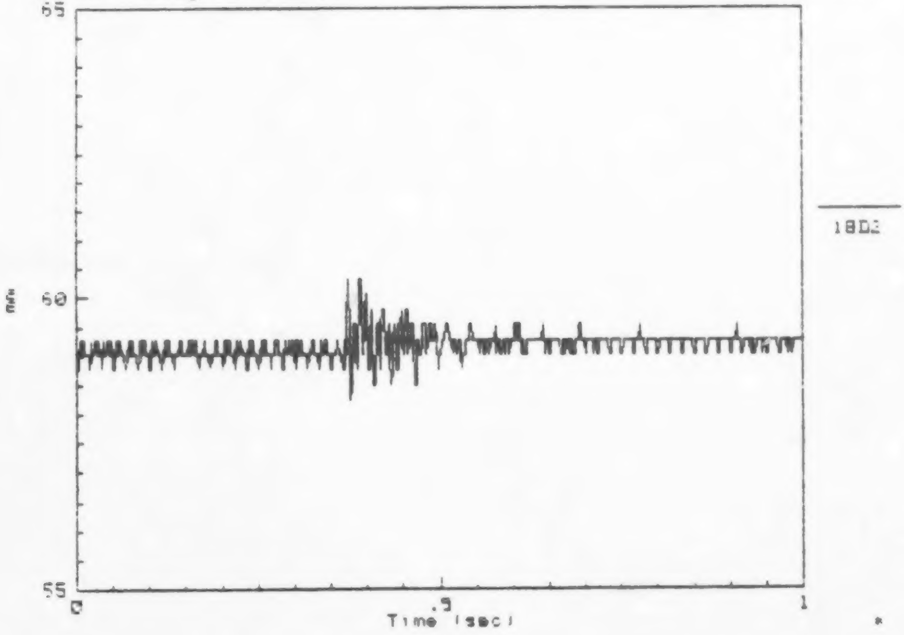
GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

Blade Single-Axis Strain **Series PBT Test 16**



GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

Blade Displacement **Series PBT Test 16**

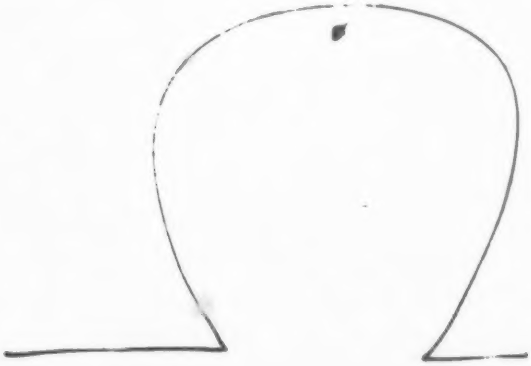


GEOTECHnical resources ltd
PROP BUSTERS
PROJECT NUMBER: 9448

```
Date: 20 May 1988
Time: 11:48:44

Test series...... PBT
Test number...... 17

*** Window 1 ***
Test duration .................. 6 Second(s)
AD-200 sample period........... 16.1 Micro-second(s)
Sample rate, aggregate ......... 62111 Hz.
Sample rate per channel ........ 3881 Hz.
Number of samples per channel .. 23292 words.
Total number of samples ........ 745344 words.
Trigger source ................. INTERNAL
Number of cards ................ 2
Number of channels per card .... 16
Total number of channels ....... 32
```



Impact point on back side of block.

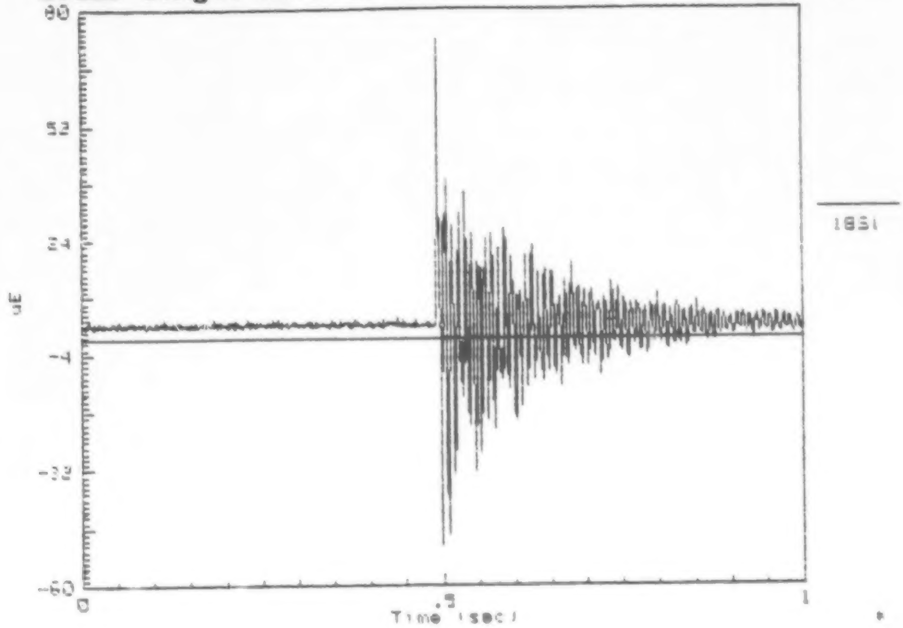
[illegible]

Transducer table for test #FBT17_HDR

```
14750 Card1:!
14760    !-----!--!--!--!--!----!--------!--------!-------!------!---------!
14770    !Card !Ch!SW!HW!Ex!Mode!  Gain  ! Offset ! Units !  Ch  !  Serial !
14780    ! no. !no!gn!gn!gn!    ! (eng/V)!  (V)   ! (/V)  !  Id  !  Number !
14790    !-----!--!--!--!--!----!--------!--------!-------!------!---------!
14800   DATA 1, 1, 1, 1, 1, "S",  107.29, 2.7124,   "mm", "BD1",  "A33380"
14810   DATA 1, 2, 1, 1, 1, "S",  107.42, 2.0726,   "mm", "BD2",  "A22090"
14820   DATA 1, 3, 1, 1, 1, "S",  107.42, 2.3608,   "mm", "BD3",  "A22091"
14830   DATA 1, 4, 1, 1, 1, "S",  6.8529, 0.0879,  "MPa","APR1",    "5817"
14840   DATA 1, 5, 1, 1, 1, "S",  5.8586, 0.0049,  "MPa","APE1",    "4986"
14850   DATA 1, 6, 1, 1, 1, "S",  6.8792, 0.0562,  "MPa","APR2",    "5723"
14860   DATA 1, 7, 1, 1, 1, "S",  6.9636, 0.0708,  "MPa","APE2",    "5815"
14870   DATA 1, 8, 1, 1, 1, "S",  5.8643, 0.0806,  "MPa","APR3",    "5883"
14880   DATA 1, 9, 1, 1, 1, "S",  6.8531, 0.0562,  "MPa","APE3",    "5885"
14890   DATA 1,10, 1, 1, 1, "S",  13.709, 0.0757,  "MPa", "BP1",    "5887"
14900   DATA 1,11, 1, 1, 1, "S",  13.712, 0.1025,  "MPa", "BP2",    "5773"
14910   DATA 1,12, 1, 1, 1, "S",  13.734, 0.0806,  "MPa", "BP3",    "5892"
14920   DATA 1,13, 1, 1, 1, "S",  13.731, 0.0708,  "MPa", "BP4",    "5889"
14930   DATA 1,14, 1, 1, 1, "S",  13.717, 0.0635,  "MPa", "BP5",    "5891"
14940   DATA 1,15, 1, 1, 2, "S",     1.0,      0,  "  V","RAMP",  "      "
14950   DATA 1,16, 5, 1, 1, "S",  1000.0,      0,   "uE","BR1B",  "      "
14960 Card2:!
14970   DATA 2, 1 ,1, 1, 2, "S",  53.906, 1.3525,   "mm", "AD1",  "A22091"
14980   DATA 2, 2, 1, 1, 2, "S",  53.634, 1.3379,   "mm", "AD2",  "A33381"
14990   DATA 2, 3, 1, 1, 2, "S",  53.608, 1.4599,   "mm", "AD3",  "A33382"
15000   DATA 2, 4, 5, 1, 1, "S",  1000.0,      0,   "uE","BR1A",  "      "
15010   DATA 2, 5, 5, 1, 1, "S",  1000.0,      0,   "uE","BR2A",  "      "
15020   DATA 2, 6, 1, 1, 1, "S",  1000.0,      0,   "uE","FSG3",  "      "
15030   DATA 2, 7, 5, 1, 1, "S",  1000.0,      0,   "uE", "BS7",  "      "
15040   DATA 2, 8, 5, 1, 1, "S",  1000.0,      0,   "uE", "BS8",  "      "
15050   DATA 2, 9, 5, 1, 1, "S",  1000.0,      0,   "uE", "BS9",  "      "
15060   DATA 2,10, 5, 1, 1, "S",  1000.0,      0,   "uE", "BS1",  "      "
15070   DATA 2,11, 5, 1, 1, "S",  1000.0,      0,   "uE","BR2B",  "      "
15080   DATA 2,12, 5, 1, 1, "S",  1000.0,      0,   "uE", "BS3",  "      "
15090   DATA 2,13, 5, 1, 1, "S",  1000.0,      0,   "uE", "BS4",  "      "
15100   DATA 2,14, 5, 1, 1, "S",  1000.0,      0,   "uE", "BS2",  "      "
15110   DATA 2,15, 5, 1, 1, "S",  1000.0, 0.2881,   "uE","BR2C",  "      "
15120   DATA 2,16, 5, 1, 1, "S",  1000.0,      0,   "uE","BR1C",  "      "
15130    !-----!--!--!--!--!----!--------!--------!-------!------!---------!
15140    !Card !Ch!SW!HW!Ex!Mode!  Gain  ! Offset ! Units !  Ch  !  Serial !
15150    ! no. !no!gn!gn!gn!    ! (Eng/V)!  (V)   ! (/V)  !  Id  !  Number !
15160    !-----!--!--!--!--!----!--------!--------!-------!------!---------!
15170 End_transducers:!
```

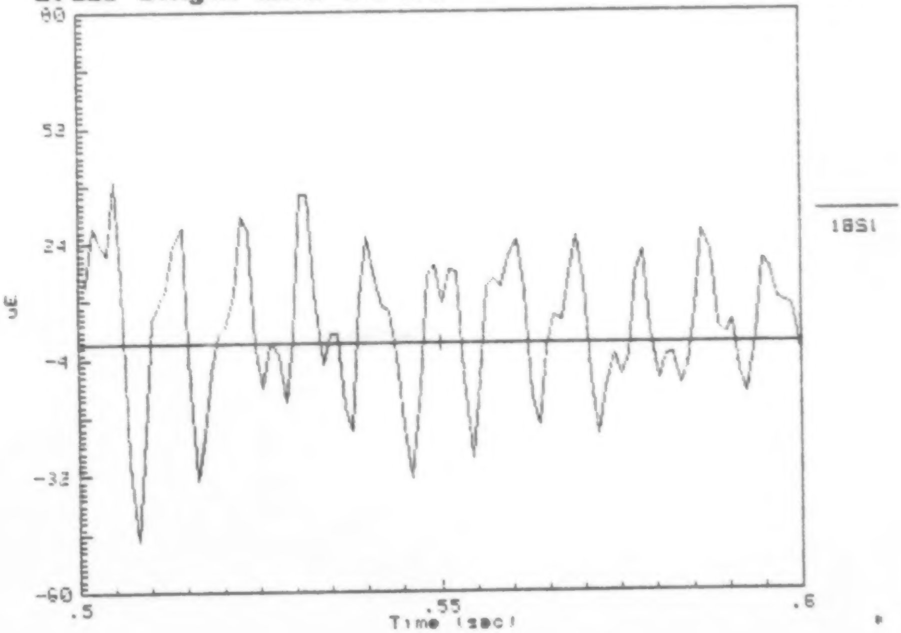
GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

Blade Single-Axis Strain **Series PBT Test 17**



GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

Blade Single-Axis Strain **Series PBT Test 17**



```
                         GEOTECHnical resources ltd
                                PROP BUSTERS
                            PROJECT NUMBER: 9448


Date: 20 May 1988
Time: 12:13:32

Test series...... PBT
Test number...... 18

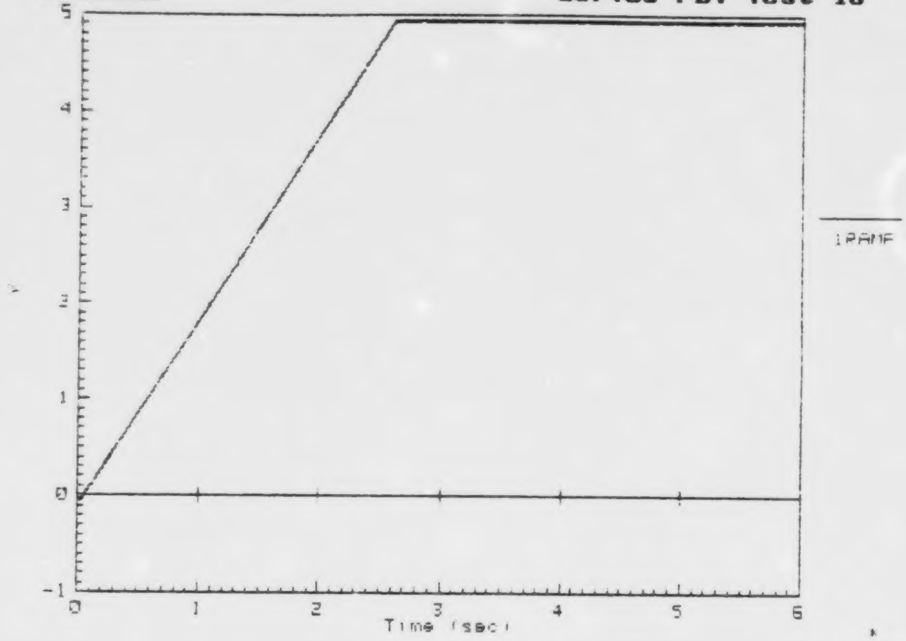
*** Window 1 ***
Test duration .................. 6 Second(s)
AD-200 sample period............ 16.1 Micro-second(s)
Sample rate, aggregate ......... 62111 Hz.
Sample rate per channel ........ 3881 Hz.
Number of samples per channel .. 23292 words.
Total number of samples ........ 745344 words.
Trigger source ................. INTERNAL
Number of cards ................ 2
Number of channels per card .... 16
Total number of channels ....... 32
```

Transducer table for test #PBT19_HDR

```
14750 Card1:!
14760    |-----|--|--|--|--|----|--------|--------|-------|------|---------|
14770    |Card |Ch|SW|HW|Ex|Mode| Gain   | Offset | Units |  Ch  |  Serial |
14780    | no. |no|gn|gn|gn|    |(eng/V)|  (V)   | (/V)  |  Id  |  Number |
14790    |-----|--|--|--|--|----|--------|--------|-------|------|---------|
14800    DATA 1, 1, 1, 1, 1, "S",  107.29, 2.7124,   "mm", "BD1",  "A33380"
14810    DATA 1, 2, 1, 1, 1, "S",  107.42, 2.0726,   "mm", "BD2",  "A22090"
14820    DATA 1, 3, 1, 1, 1, "S",  107.42, 2.3608,   "mm", "BD3",  "A22091"
14830    DATA 1, 4, 1, 1, 1, "S",  6.8529, 0.0879,  "MPa","APR1",    "5817"
14840    DATA 1, 5, 1, 1, 1, "S",  6.9586, 0.0049,  "MPa","APE1",    "4986"
14850    DATA 1, 6, 1, 1, 1, "S",  6.8792, 0.0562,  "MPa","APR2",    "5723"
14860    DATA 1, 7, 1, 1, 1, "S",  6.8636, 0.0708,  "MPa","APE2",    "5815"
14870    DATA 1, 8, 1, 1, 1, "S",  6.8643, 0.0806,  "MPa","APR3",    "5883"
14880    DATA 1, 9, 1, 1, 1, "S",  6.8531, 0.0562,  "MPa","APE3",    "5885"
14890    DATA 1,10, 1, 1, 1, "S",  13.709, 0.0757,  "MPa", "BP1",    "5887"
14900    DATA 1,11, 1, 1, 1, "S",  13.712, 0.1025,  "MPa", "BP2",    "5773"
14910    DATA 1,12, 1, 1, 1, "S",  13.734, 0.0806,  "MPa", "BP3",    "5892"
14920    DATA 1,13, 1, 1, 1, "S",  13.731, 0.0708,  "MPa", "BP4",    "5889"
14930    DATA 1,14, 1, 1, 1, "S",  13.717, 0.0635,  "MPa", "BP5",    "5891"
14940    DATA 1,15, 1, 1, 2, "S",     1.0,      0,  "  V","RAMP",  "        "
14950    DATA 1,16, 1, 1, 1, "S",  2000.0,      0,   "uE","BR1B",  "        "
14960 Card2:!
14970    DATA 2, 1 ,1, 1, 2, "S",  53.906, 1.3525,   "mm", "AD1",  "A22091"
14980    DATA 2, 2, 1, 1, 2, "S",  53.634, 1.3379,   "mm", "AD2",  "A33381"
14990    DATA 2, 3, 1, 1, 2, "S",  53.608, 1.4599,   "mm", "AD3",  "A33382"
15000    DATA 2, 4, 1, 1, 1, "S",  2000.0,      0,   "uE","BR1A",  "        "
15010    DATA 2, 5, 1, 1, 1, "S",  2000.0,      0,   "uE","BR2A",  "        "
15020    DATA 2, 6, 1, 1, 1, "S",  1000.0,      0,   "uE","FSG3",  "        "
15030    DATA 2, 7, 1, 1, 1, "S",  2000.0,      0,   "uE", "BS7",  "        "
15040    DATA 2, 8, 1, 1, 1, "S",  2000.0,      0,   "uE", "BS8",  "        "
15050    DATA 2, 9, 1, 1, 1, "S",  2000.0,      0,   "uE", "BS9",  "        "
15060    DATA 2,10, 1, 1, 1, "S",  2000.0,      0,   "uE", "BS1",  "        "
15070    DATA 2,11, 1, 1, 1, "S",  2000.0,      0,   "uE","BR2B",  "        "
15080    DATA 2,12, 1, 1, 1, "S",  2000.0,      0,   "uE", "BS3",  "        "
15090    DATA 2,13, 1, 1, 1, "S",  2000.0,      0,   "uE", "BS4",  "        "
15100    DATA 2,14, 1, 1, 1, "S",  2000.0,      0,   "uE", "BS2",  "        "
15110    DATA 2,15, 1, 1, 1, "S",  2000.0,      0,   "uE","BR2C",  "        "
15120    DATA 2,16, 1, 1, 1, "S",  2000.0,      0,   "uE","BR1C",  "        "
15130    |-----|--|--|--|--|----|--------|--------|-------|------|---------|
15140    |Card |Ch|SW|HW|Ex|Mode| Gain   | Offset | Units |  Ch  |  Serial |
15150    | no. |no|gn|gn|gn|    |(Eng/V)|  (V)   | (/V)  |  Id  |  Number |
15160    |-----|--|--|--|--|----|--------|--------|-------|------|---------|
15170 End_transducers:!
```

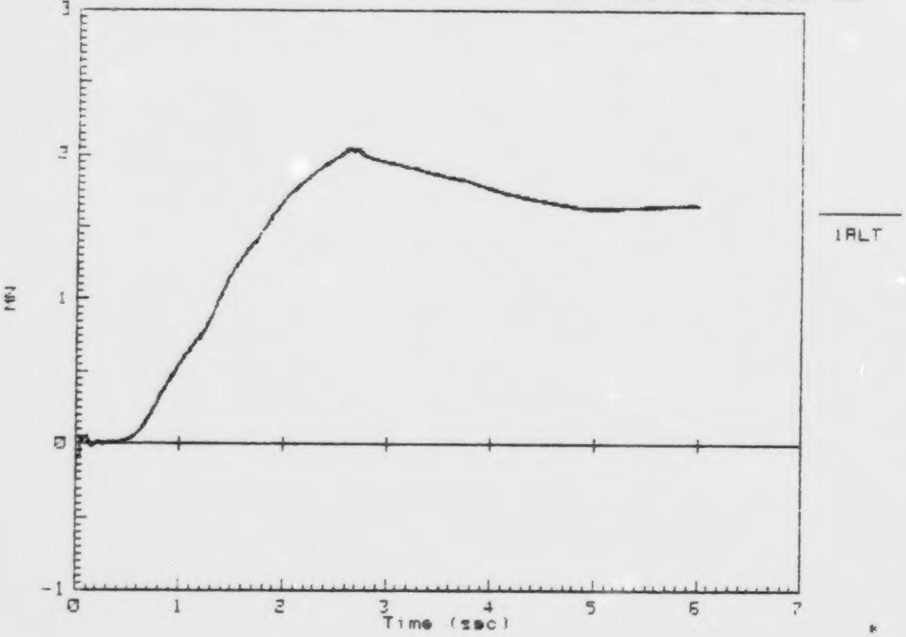
GEOTECHnical Resources Ltd.   ANALYSIS DATE:20 May 1988

Command **Series PBT Test 18**



GEOTECHnical Resources Ltd.   ANALYSIS DATE:20 May 1988

Total Load **Series PBT Test 18**



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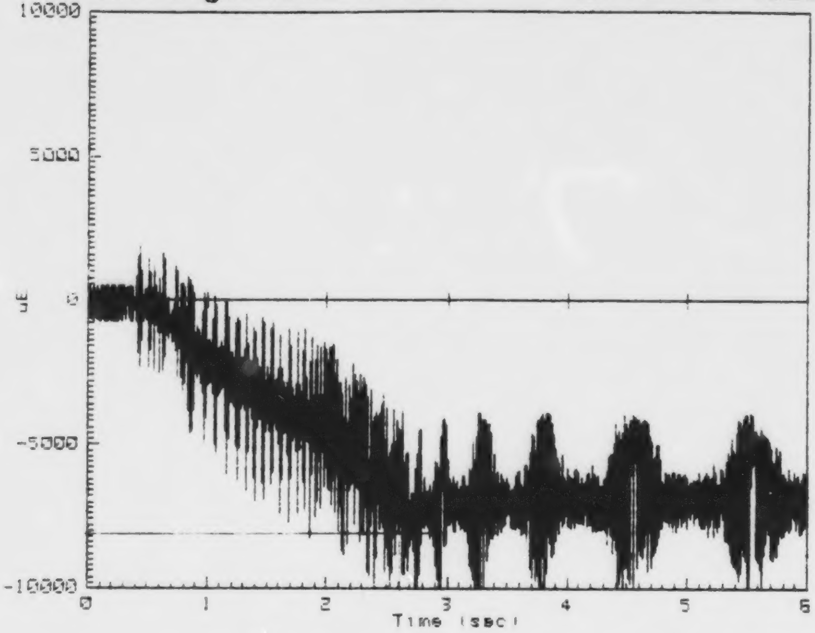
GEOTECHnical Resources Ltd.   ANALYSIS DATE:20 May 1988

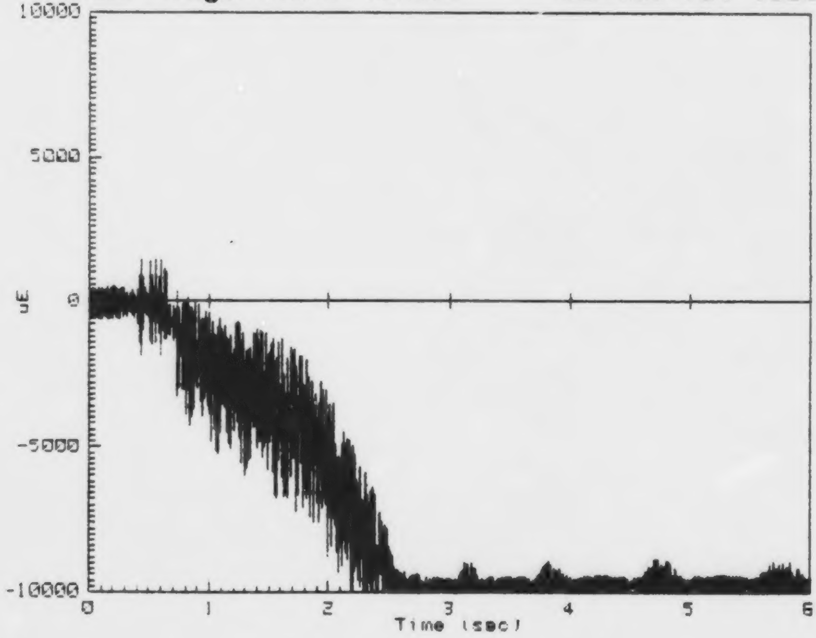
Blade Single-Axis Strain   Series PBT Test 18



1853

GEOTECHnical Resources Ltd.   ANALYSIS DATE:20 May 1988

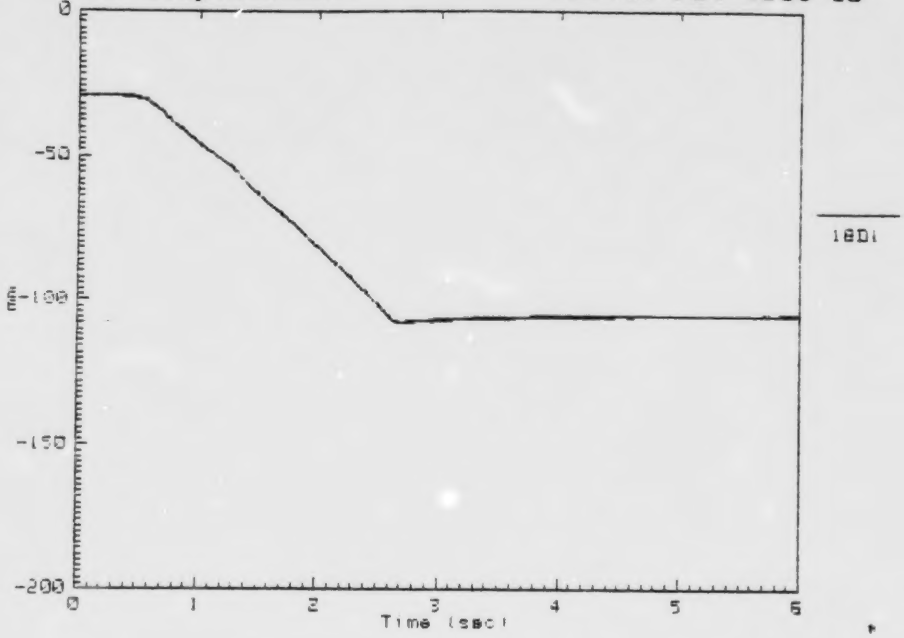
Blade Single-Axis Strain   Series PBT Test 18



1854

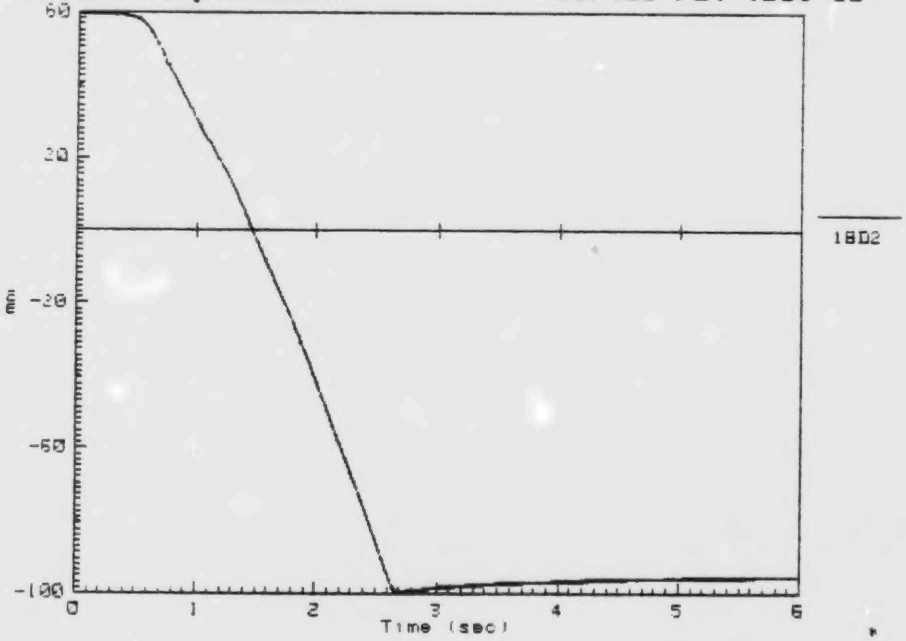
GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

Blade Displacement **Series PBT Test 18**



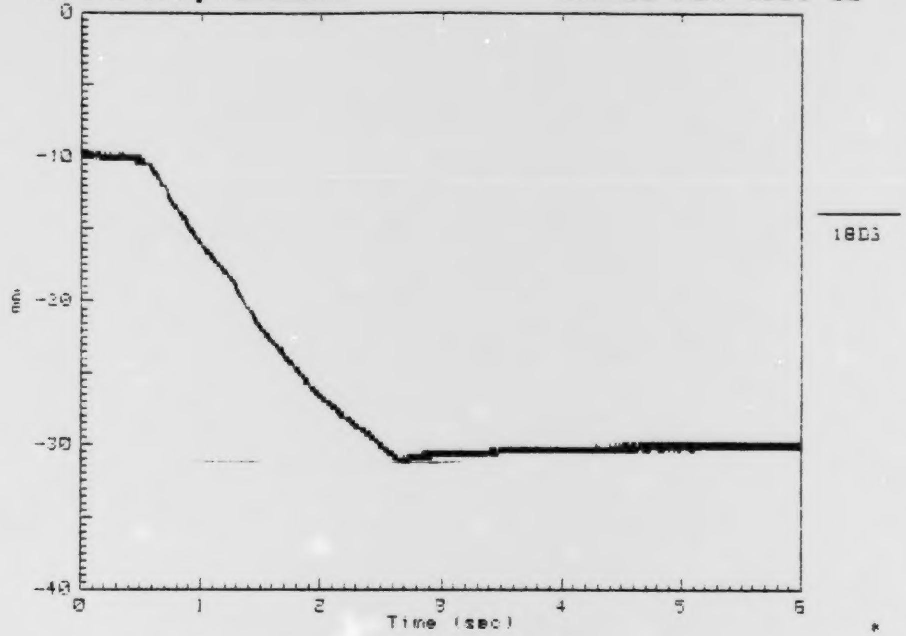
GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

Blade Displacement **Series PBT Test 18**

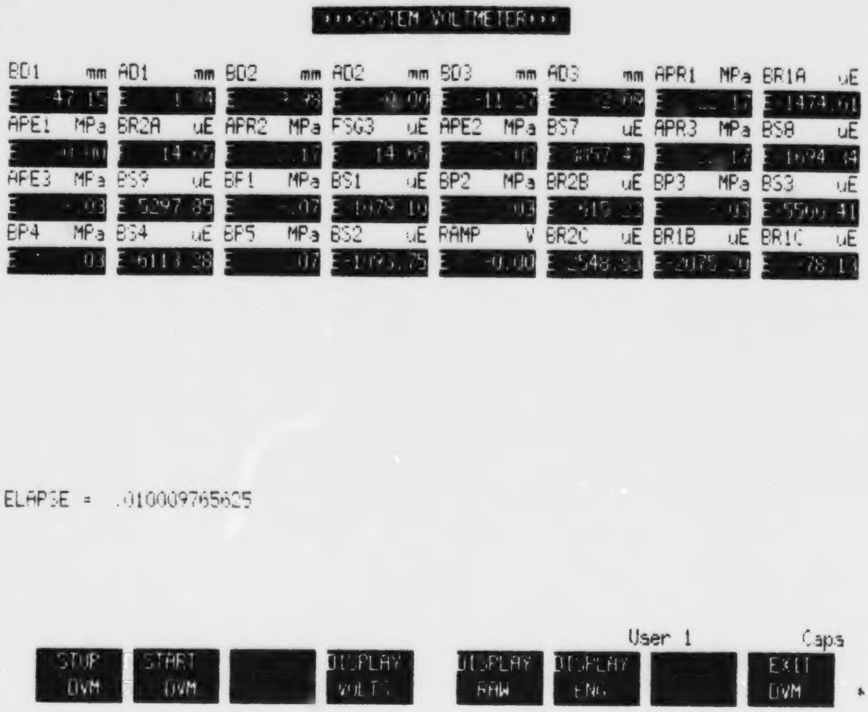


GEOTECHnical Resources Ltd.   ANALYSIS DATE:20 May 1988

Blade Displacement **Series PBT Test 18**



ZERO LEVELS AFTER RETRACTION OF TEST 18



```
***SYSTEM VOLTMETER***

BD1      mm  AD1      mm  BD2      mm  AD2      mm  BD3      mm  AD3      mm  APR1    MPa  BR1A     uE
   -47.15        1.34        9.38       -0.00      -11.27        2.09         .17    -1474.61
APE1    MPa  BR2A     uE  APR2    MPa  FSG3     uE  APE2    MPa  BS7      uE  APR3    MPa  BS8      uE
    -0.00       14.07         .17       14.65         .10      8857.4         .17    -1694.48
APE3    MPa  BS9      uE  BF1     MPa  BS1      uE  BP2     MPa  BR2B     uE  BP3     MPa  BS3      uE
     -.03     5297.85        -.07    -1079.10         .03      615.33        -.03    -5566.41
BP4     MPa  BS4      uE  BP5     MPa  BS2      uE  RAMP      V  BR2C     uE  BR1B     uE  BR1C     uE
      .03    -6113.38         .07    -1095.75       -0.00    -2548.83    -2075.20      -78.13

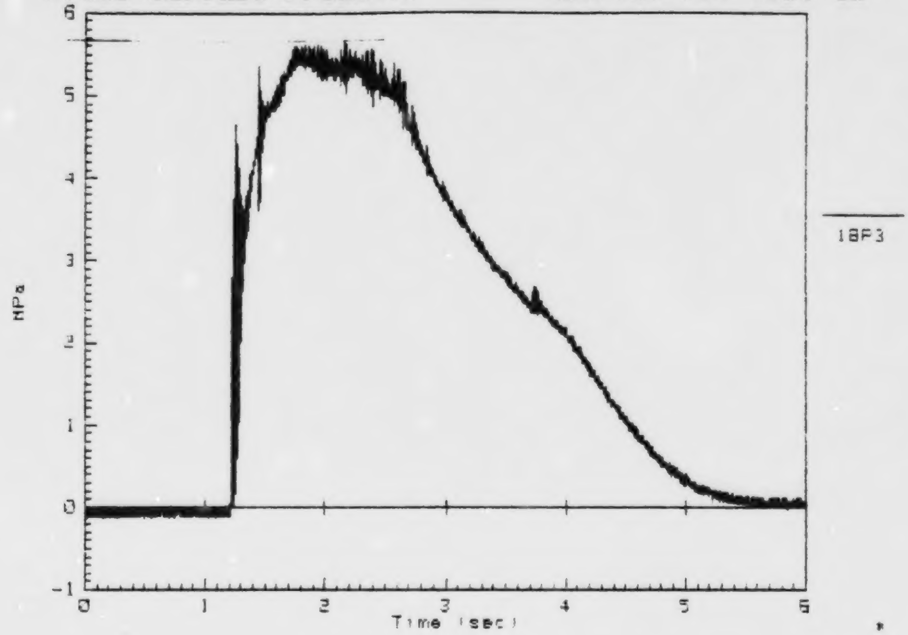
ELAPSE =  .010009765625

                                                       User 1         Caps
```

STOP DVM
START DVM
DISPLAY VOLTS
DISPLAY RAW
DISPLAY ENG
EXIT DVM

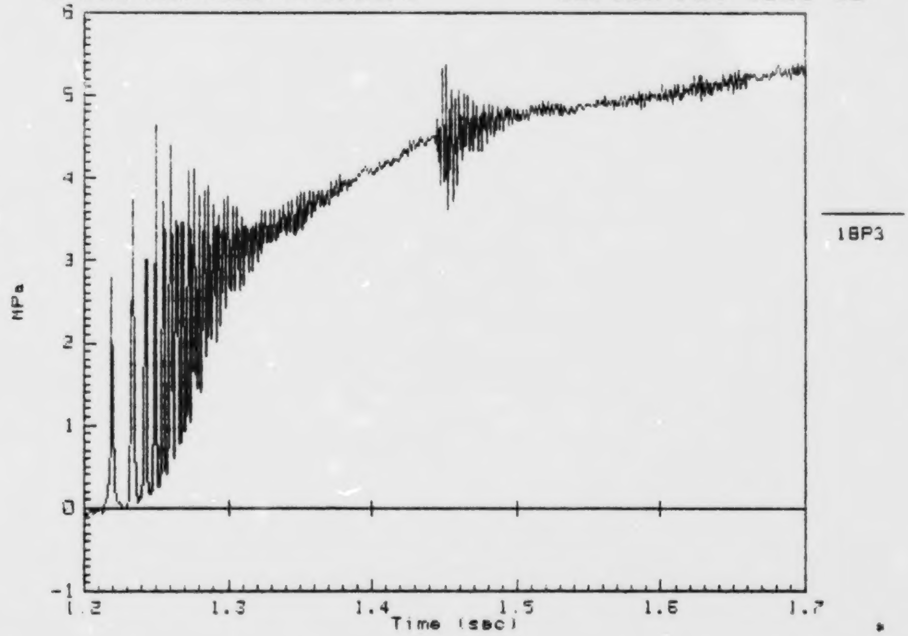
GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

Blade Surface Pressure **Series PBT Test 18**



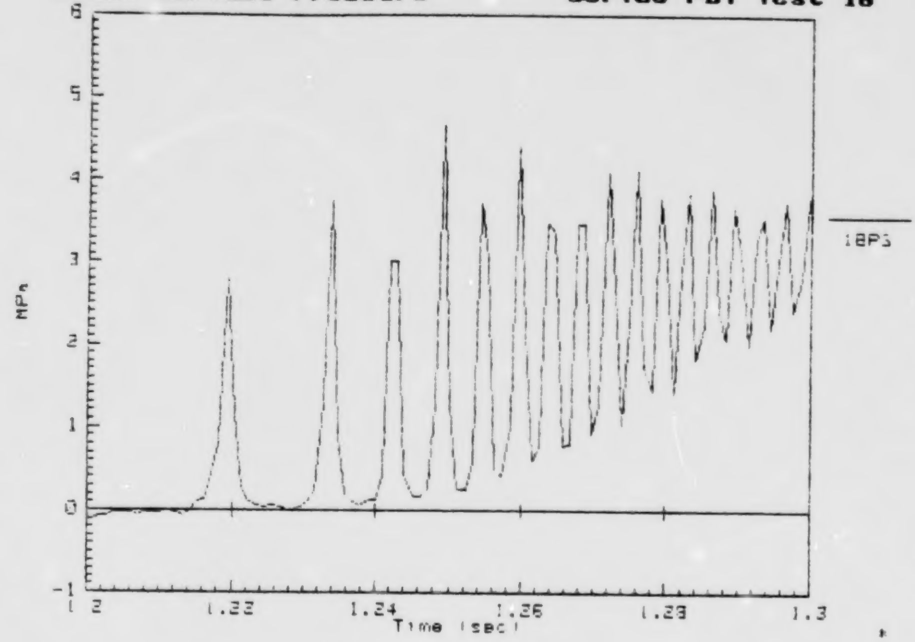
GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

Blade Surface Pressure **Series PBT Test 18**



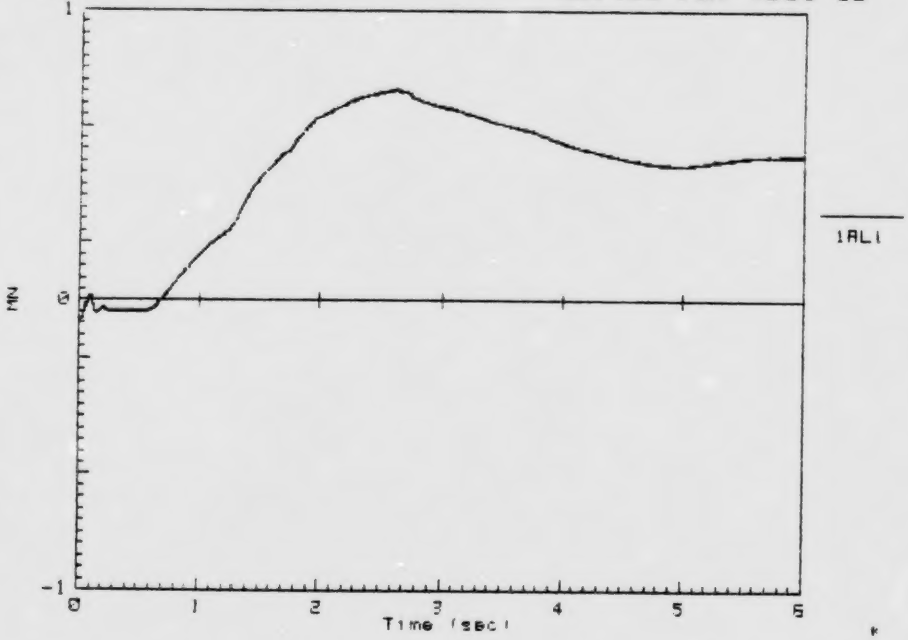
GEOTECHnical Resources Ltd.   ANALYSIS DATE:20 May 1988

Blade Surface Pressure   Series PBT Test 18



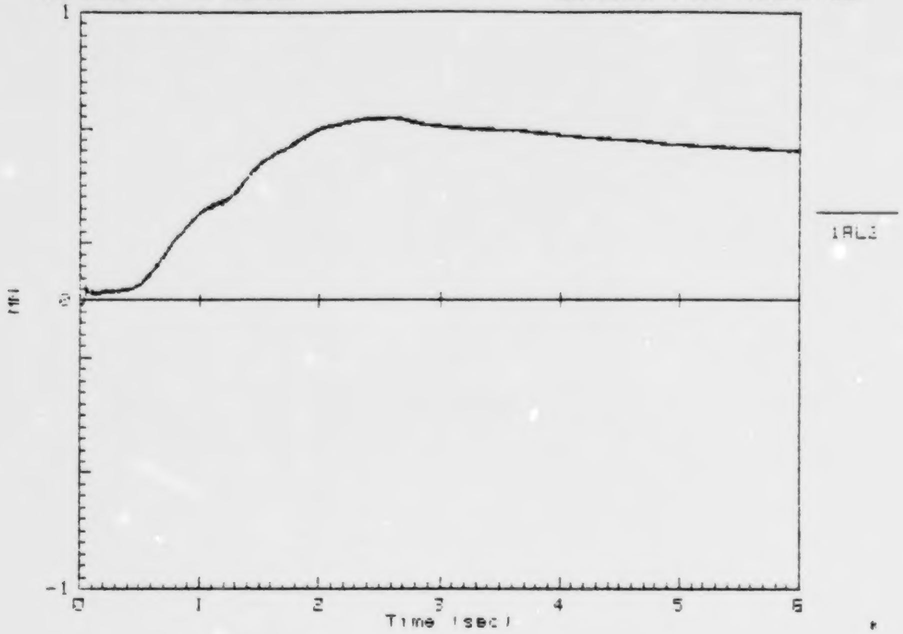
GEOTECHnical Resources Ltd.   ANALYSIS DATE:20 May 1988

Actuator 1 Load   Series PBT Test 18



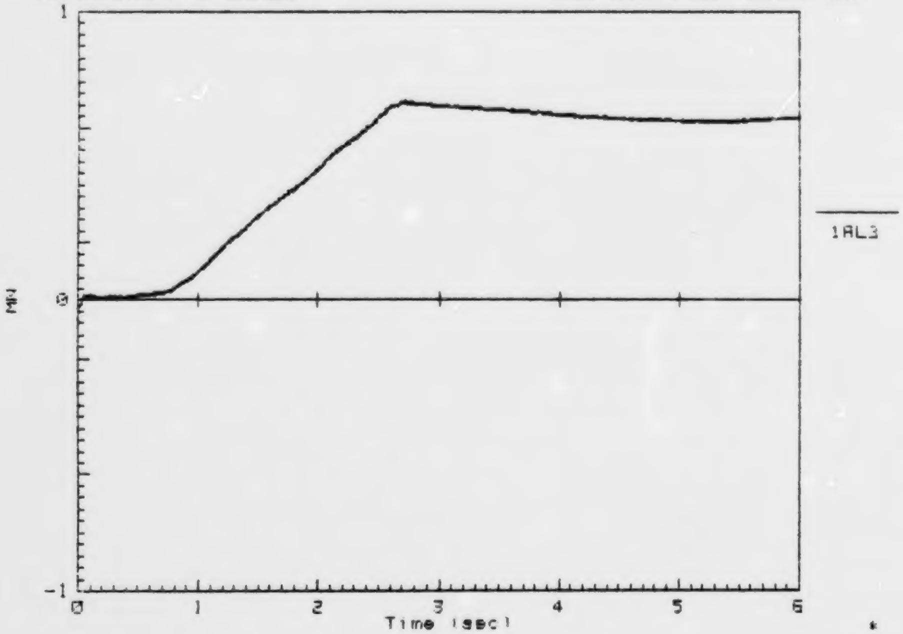
GEOTECHnical Resources Ltd.   ANALYSIS DATE:20 May 1988

Actuator 2 Load **Series PBT Test 18**



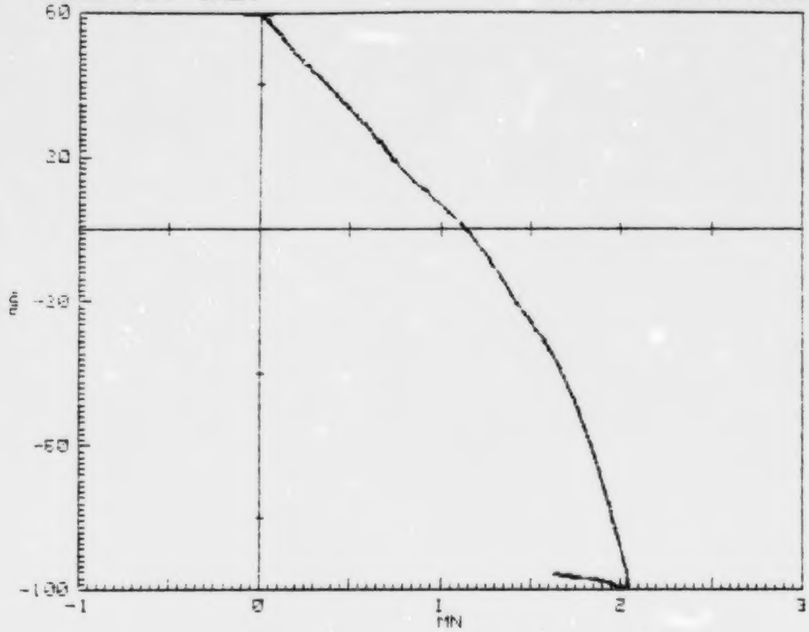
GEOTECHnical Resources Ltd.   ANALYSIS DATE:20 May 1988

Actuator 3 Load **Series PBT Test 18**



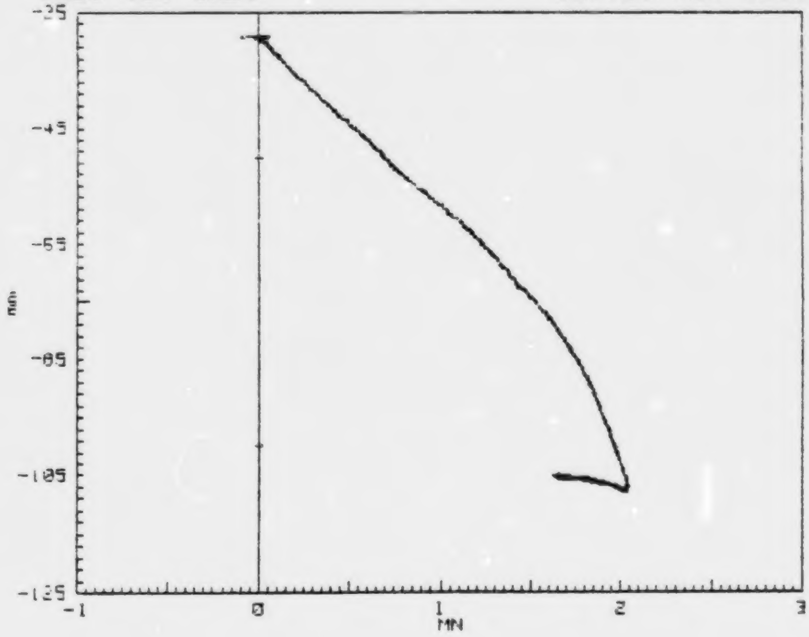
GEOTECHnical Resources Ltd.   ANALYSIS DATE:20 May 1988

1BD2 vs. 1ALT   **Series PBT Test 18**



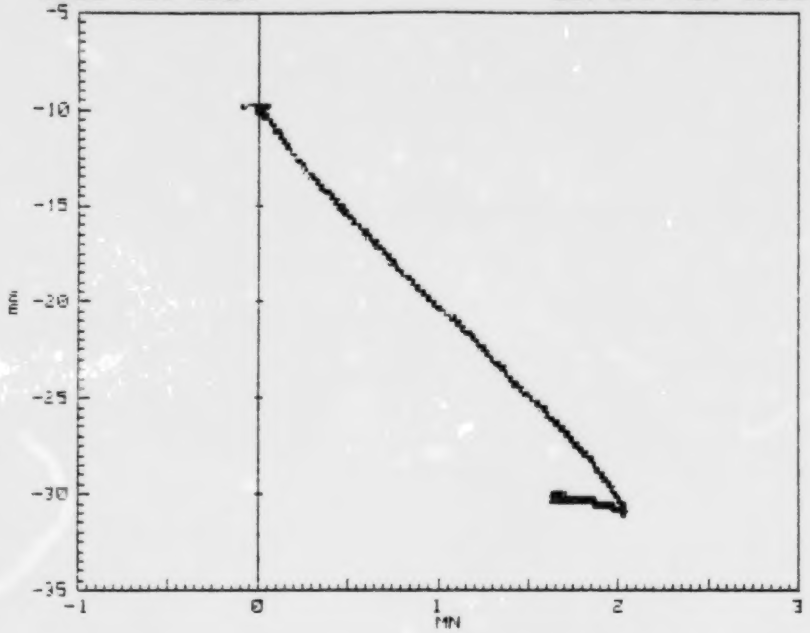
GEOTECHnical Resources Ltd.   ANALYSIS DATE:20 May 1988

1BD1 vs. 1ALT   **Series PBT Test 18**



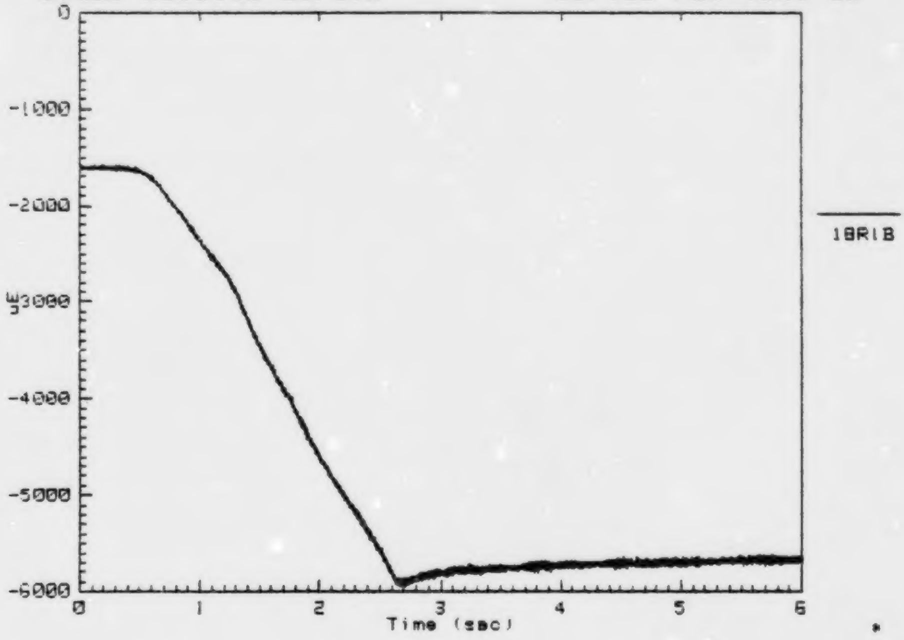
GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

1BD3 vs. 1ALT **Series PBT Test 18**



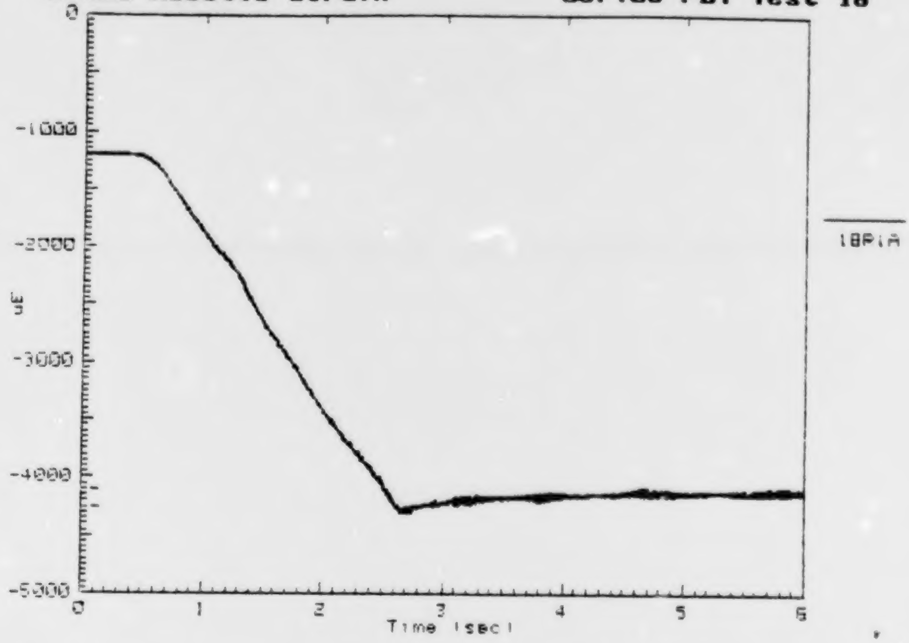
GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

Blade Rosette Strain **Series PBT Test 18**



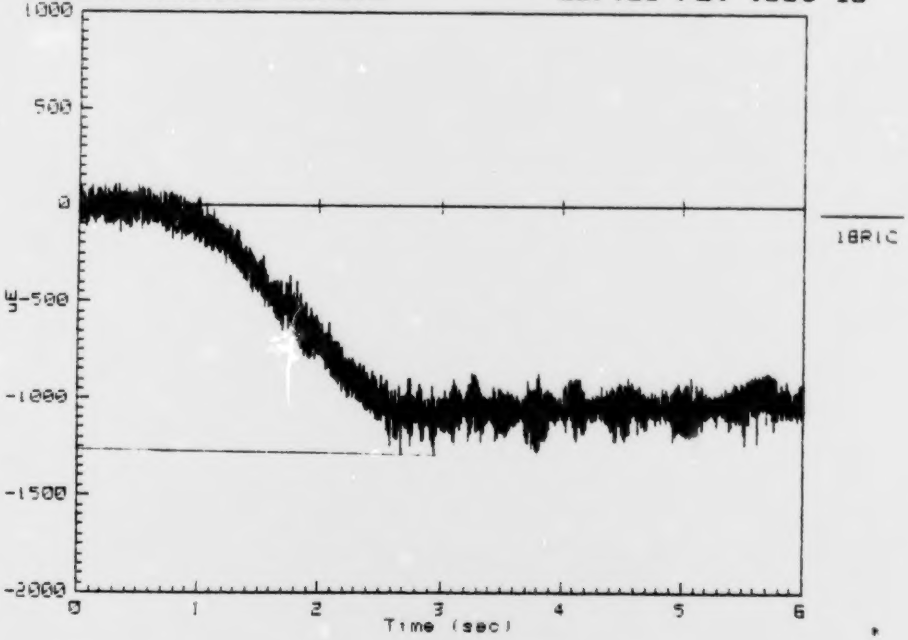
GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

Blade Rosette Strain **Series PBT Test 18**



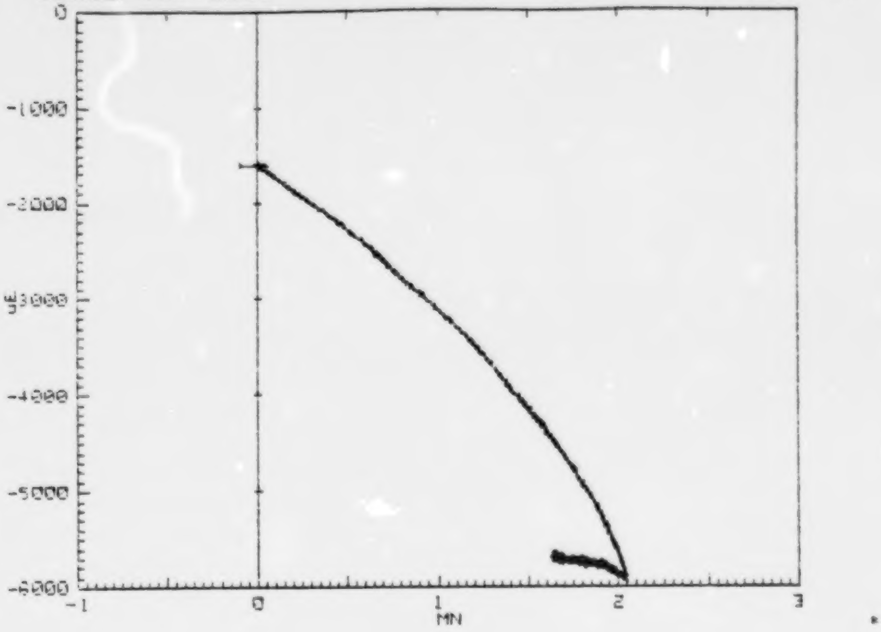
GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

Blade Rosette Strain **Series PBT Test 18**



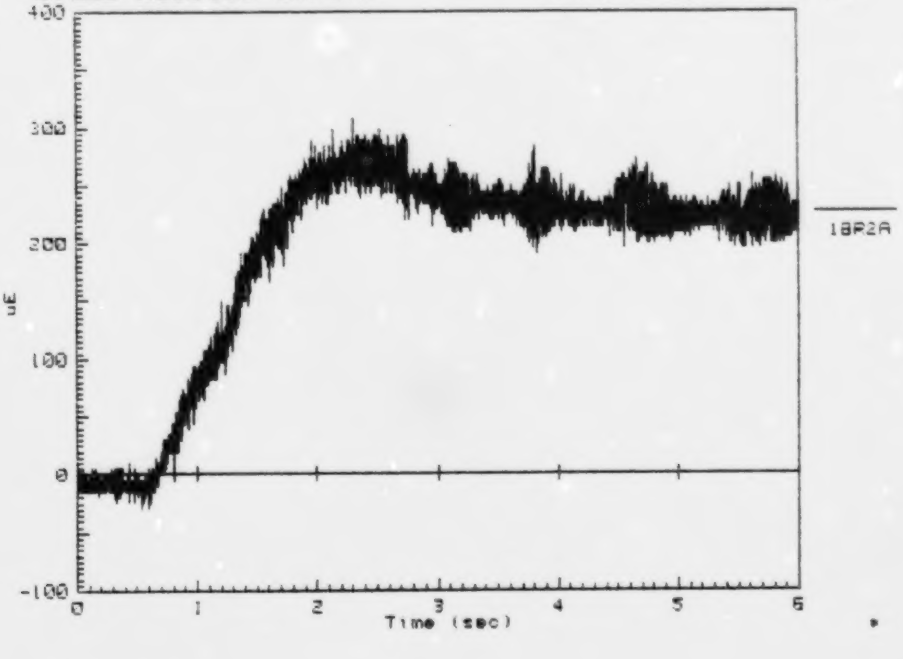
GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

1BR1B vs. 1ALT **Series PBT Test 18**



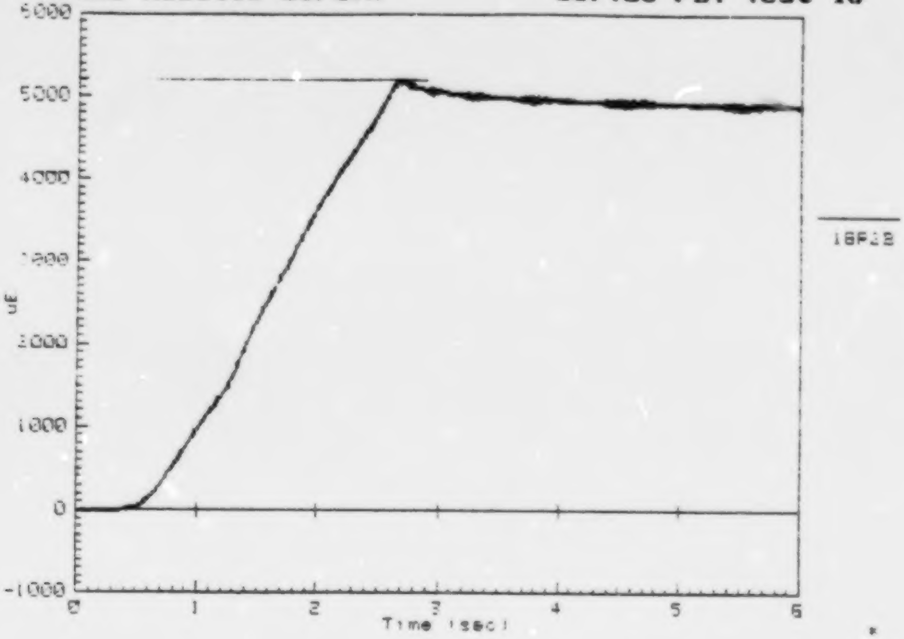
GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

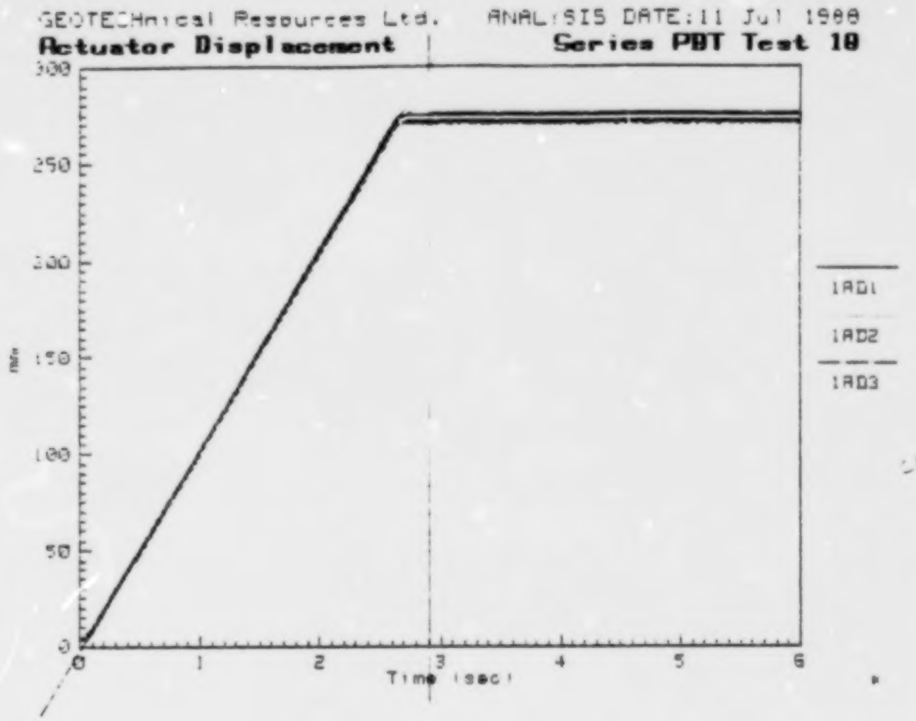
Blade Rosette Strain **Series PBT Test 18**



GEOTECHnical Resources Ltd.   ANALYSIS DATE:30 May 1989

Blade Rosette Strain   **Series PBT Test 18**





GEOTECHnical Resources Ltd.   ANALYSIS DATE: 11 Jul 1988

Actuator Displacement   **Series PBT Test 10**

v = 300 mm / 2.9 s

≈ 103.5 mm/s

```
                         GEOTECHnical resources ltd
                                PROP BUSTERS
                           PROJECT NUMBER: 9448


Date: 20 May 1988
Time: 14:25:49

Test series...... PBT
Test number...... 19

*** Window 1 ***
Test duration ................... 6 Second(s)
AD-200 sample period............. 16.1 Micro-second(s)
Sample rate, aggregate .......... 62111 Hz.
Sample rate per channel ......... 3881 Hz.
Number of samples per channel .. 23292 words.
Total number of samples ......... 745344 words.
Trigger source .................. INTERNAL
Number of cards ................. 2
Number of channels per card .... 16
Total number of channels ....... 32
```

Transducer table for test #PBT19_HDR

```
14750 Card1:!
14760   |-----|--|--|--|--|----|--------|--------|-------|------|---------|
14770   |Card |Ch|SW|HW|Ex|Mode| Gain   | Offset | Units |  Ch  |  Serial |
14780   | no. |no|gn|gn|gn|    | (eng/V)|  (V)   | (/V)  |  Id  |  Number |
14790   |-----|--|--|--|--|----|--------|--------|-------|------|---------|
14800   DATA 1, 1, 1, 1, 1, "S",  107.29, 2.7124,   "mm", "BD1",  "A33380"
14810   DATA 1, 2, 1, 1, 1, "S",  107.42, 3.4204,   "mm", "BD2",  "A22090"
14820   DATA 1, 3, 1, 1, 1, "S",  107.42, 2.3608,   "mm", "BD3",  "A22091"
14830   DATA 1, 4, 1, 1, 1, "S",  6.9529, 0.0879,  "MPa","APR1",    "5817"
14840   DATA 1, 5, 1, 1, 1, "S",  6.8566, 0.0049,  "MPa","APE1",    "4996"
14850   DATA 1, 6, 1, 1, 1, "S",  6.8792, 0.0562,  "MPa","APR2",    "5723"
14860   DATA 1, 7, 1, 1, 1, "S",  6.9636, 0.0708,  "MPa","APE2",    "5815"
14870   DATA 1, 8, 1, 1, 1, "S",  6.8643, 0.0806,  "MPa","APR3",    "5883"
14880   DATA 1, 9, 1, 1, 1, "S",  6.9531, 0.0562,  "MPa","APE3",    "5885"
14890   DATA 1,10, 1, 1, 1, "S",  13.709, 0.0757,  "MPa", "BP1",    "5887"
14900   DATA 1,11, 1, 1, 1, "S",  13.712, 0.1025,  "MPa", "BP2",    "5773"
14910   DATA 1,12, 1, 1, 1, "S",  13.734, 0.0806,  "MPa", "BP3",    "5892"
14920   DATA 1,13, 1, 1, 1, "S",  13.731, 0.0708,  "MPa", "BP4",    "5889"
14930   DATA 1,14, 1, 1, 1, "S",  13.717, 0.0635,  "MPa", "BP5",    "5891"
14940   DATA 1,15, 1, 1, 2, "S",     1.0,      0,  "  V","RAMP",  "       "
14950   DATA 1,16, 1, 1, 1, "S",  2000.0,      0,   "uE","BR1B",  "       "
14960 Card2:!
14970   DATA 2, 1 ,1, 1, 2, "S",  53.906, 1.3525,   "mm", "AD1",  "A22091"
14980   DATA 2, 2, 1, 1, 2, "S",  53.634, 1.3379,   "mm", "AD2",  "A33381"
14990   DATA 2, 3, 1, 1, 2, "S",  53.608, 1.4599,   "mm", "AD3",  "A33382"
15000   DATA 2, 4, 1, 1, 1, "S",  2000.0,      0,   "uE","BR1A",  "       "
15010   DATA 2, 5, 1, 1, 1, "S",  2000.0,      0,   "uE","BR2A",  "       "
15020   DATA 2, 6, 1, 1, 1, "S",  1000.0,      0,   "uE","FSG3",  "       "
15030   DATA 2, 7, 1, 1, 1, "S",  2000.0,      0,   "uE", "BS7",  "       "
15040   DATA 2, 8, 1, 1, 1, "S",  2000.0,      0,   "uE", "BS8",  "       "
15050   DATA 2, 9, 1, 1, 1, "S",  2000.0,      0,   "uE", "BS9",  "       "
15060   DATA 2,10, 1, 1, 1, "S",  2000.0,      0,   "uE", "BS1",  "       "
15070   DATA 2,11, 1, 1, 1, "S",  2000.0,      0,   "uE","BR2B",  "       "
15080   DATA 2,12, 1, 1, 1, "S",  2000.0,      0,   "uE", "BS3",  "       "
15090   DATA 2,13, 1, 1, 1, "S",  2000.0,      0,   "uE", "BS4",  "       "
15100   DATA 2,14, 1, 1, 1, "S",  2000.0,      0,   "uE", "BS2",  "       "
15110   DATA 2,15, 1, 1, 1, "S",  2000.0,      0,   "uE","BR2C",  "       "
15120   DATA 2,16, 1, 1, 1, "S",  2000.0,      0,   "uE","BR1C",  "       "
15130   |-----|--|--|--|--|----|--------|--------|-------|------|---------|
15140   |Card |Ch|SW|HW|Ex|Mode| Gain   | Offset | Units |  Ch  |  Serial |
15150   | no. |no|gn|gn|gn|    | (Eng/V)|  (V)   | (/V)  |  Id  |  Number |
15160   |-----|--|--|--|--|----|--------|--------|-------|------|---------|
15170 End_transducers:!
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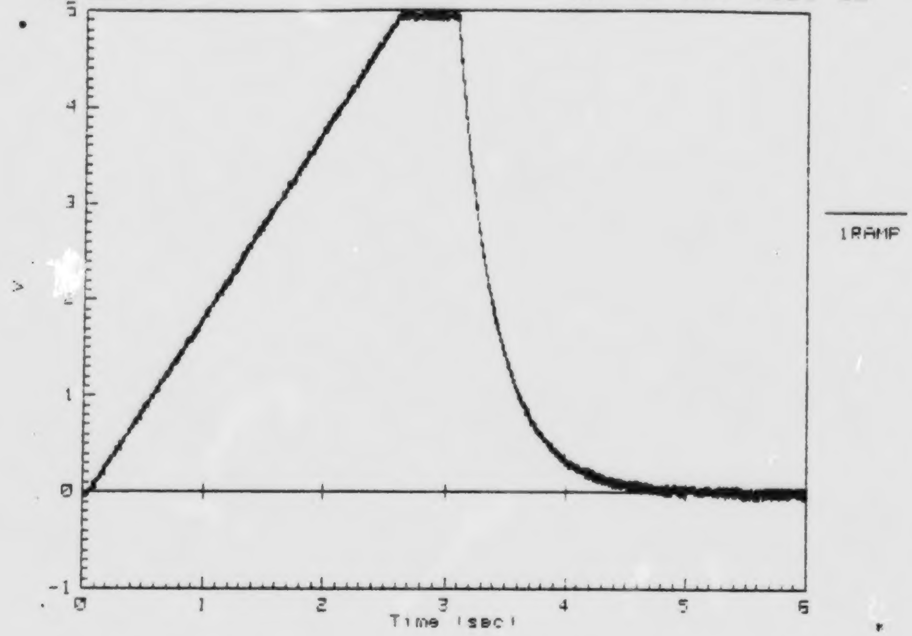
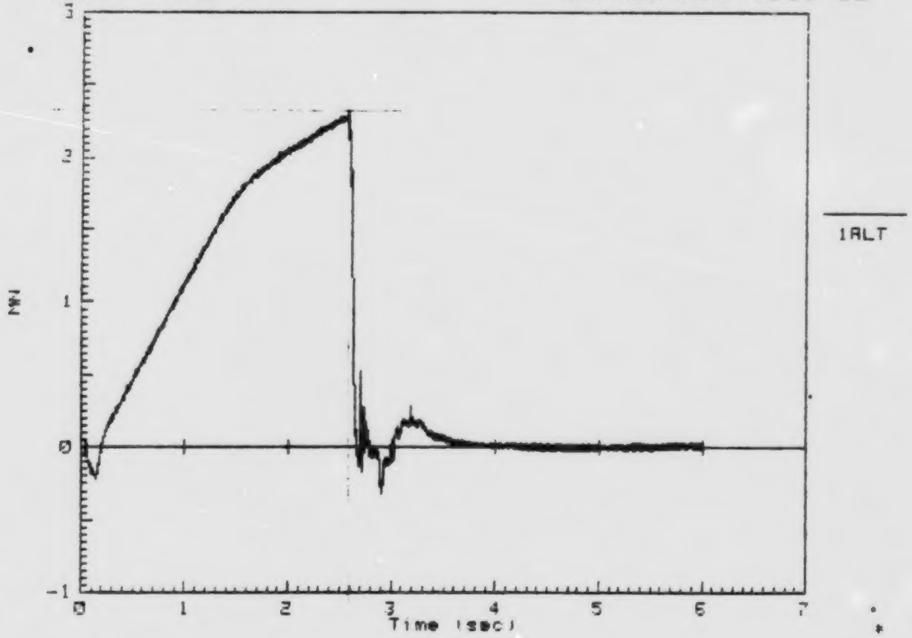
GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

Command **Series PBT Test 19**



GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

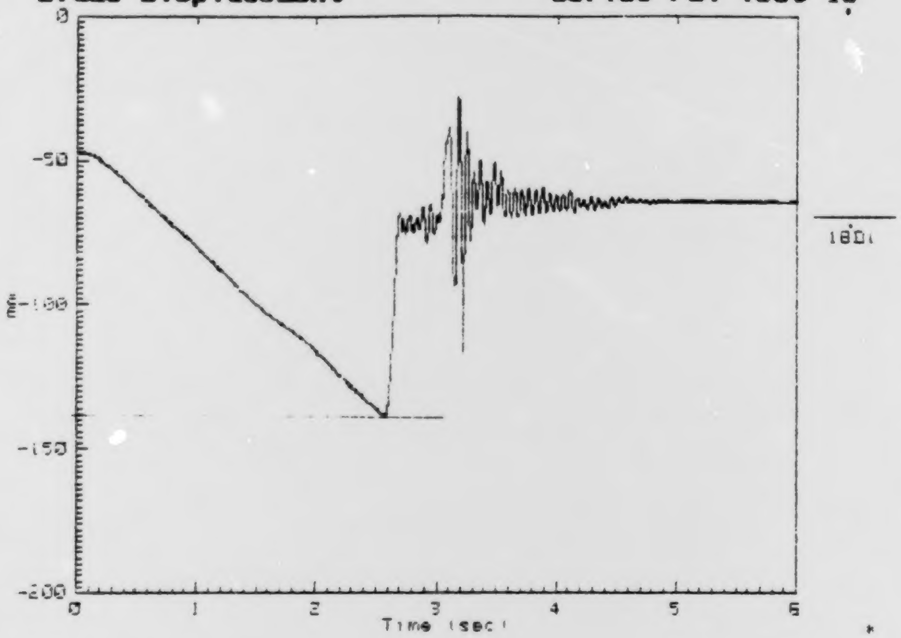
Total Load **Series PBT Test 19**



Peak load
≃ 2.35 MN
@ 2.6 s

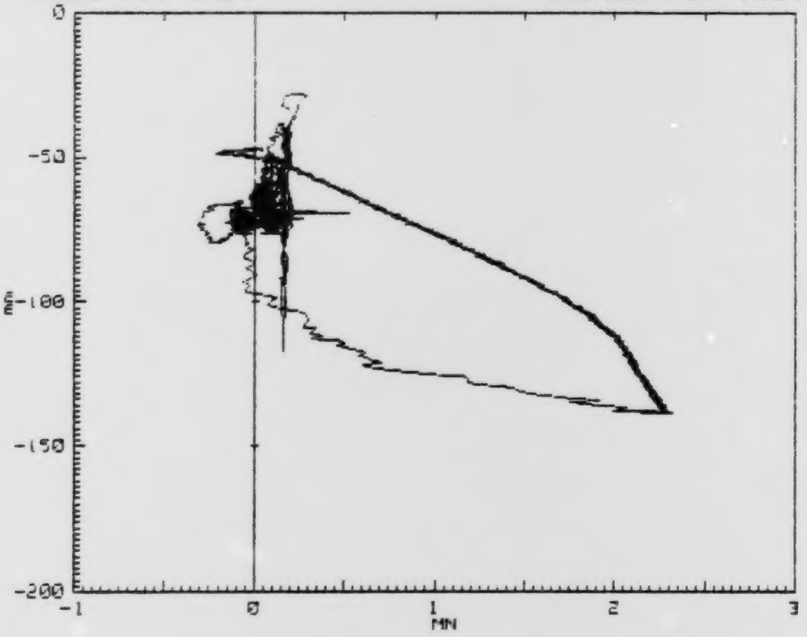
GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

Blade Displacement **Series PBT Test 19**



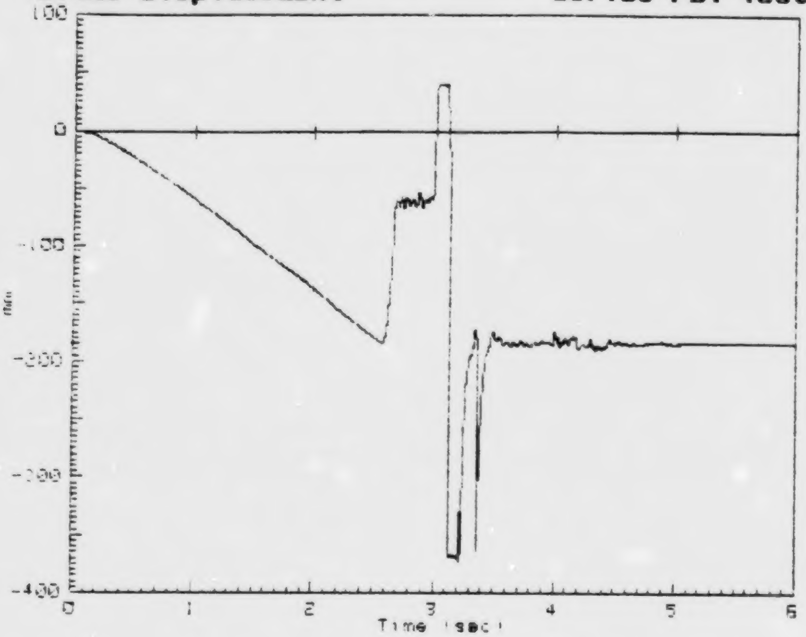
GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

1BD1 vs. 1ALT **Series PBT Test 19**



GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

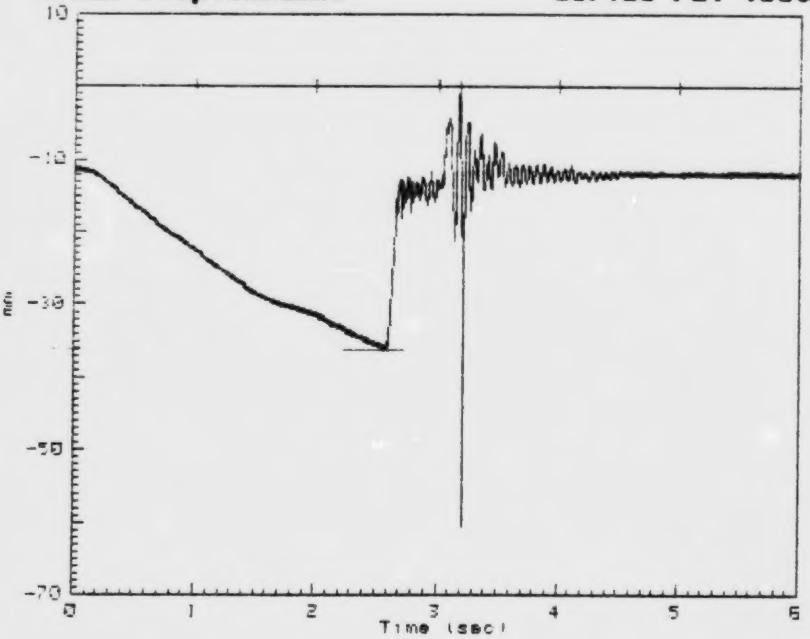
Blade Displacement **Series PBT Test 19**



18D2

GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

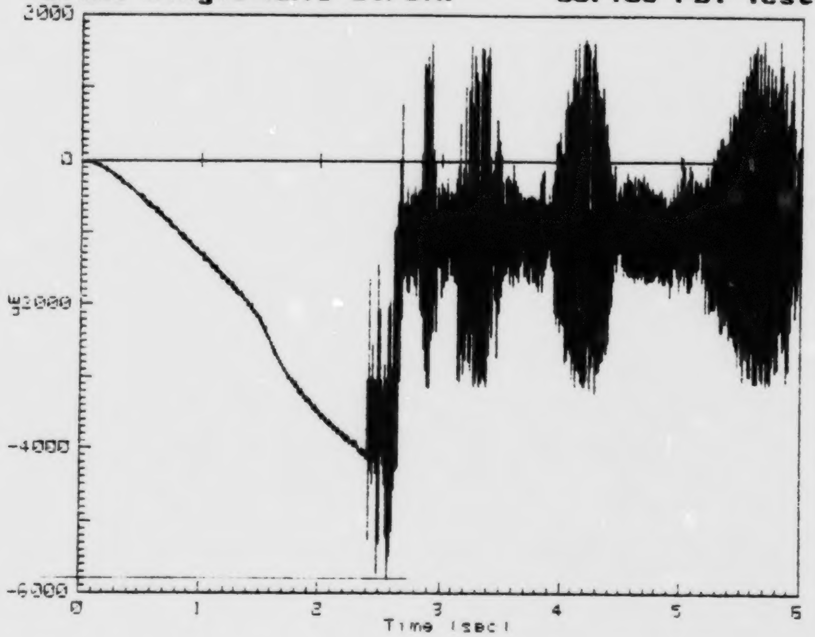
Blade Displacement **Series PBT Test 19**



18D3

GEOTECHnical Resources Ltd.   ANALYSIS DATE:20 May 1988

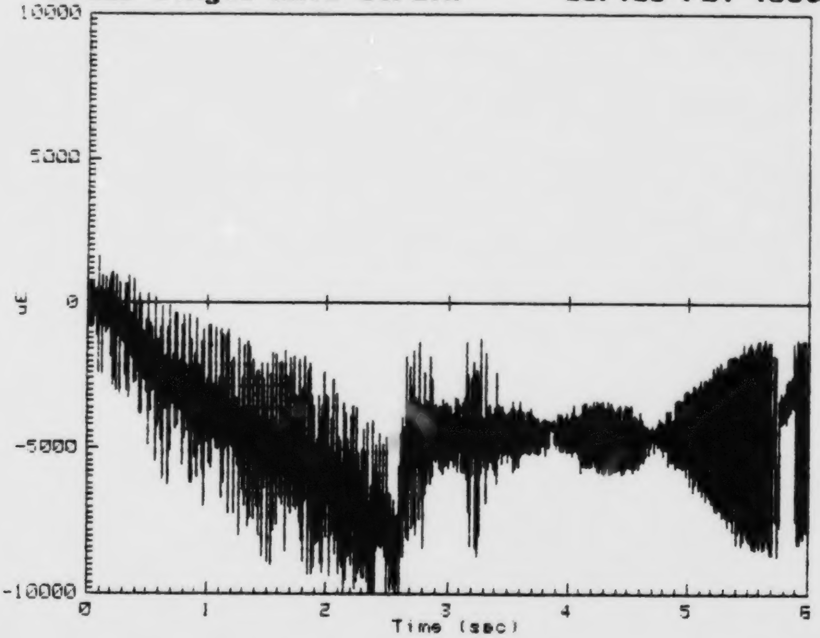
Blade Single-Axis Strain   **Series PBT Test 19**



1851

GEOTECHnical Resources Ltd.   ANALYSIS DATE:20 May 1988

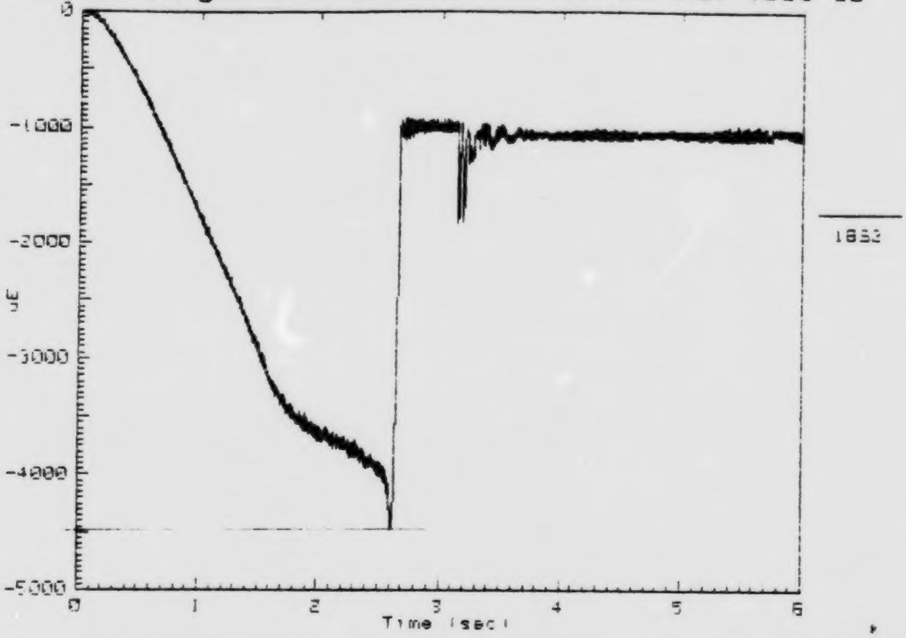
Blade Single-Axis Strain   **Series PBT Test 19**



1833

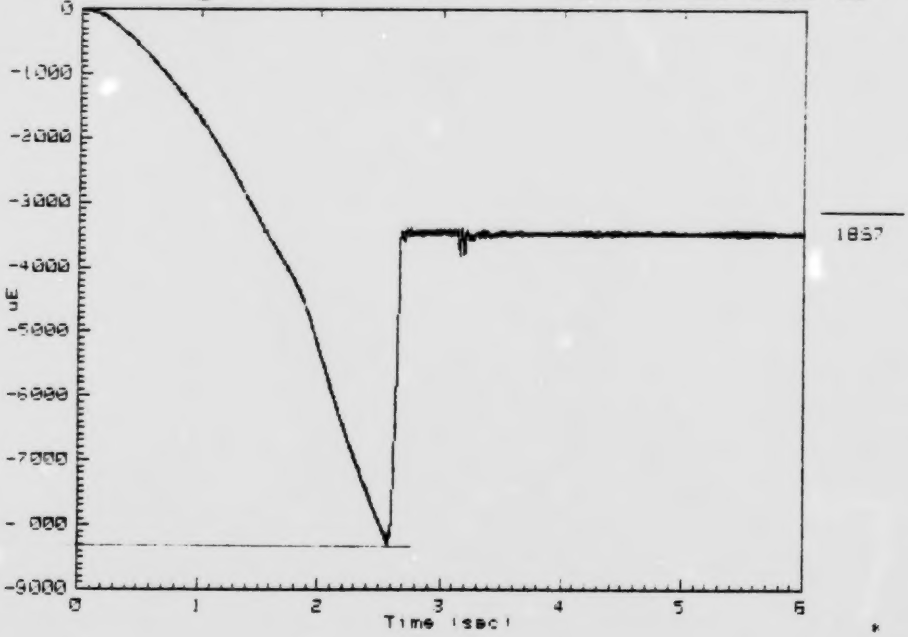
GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

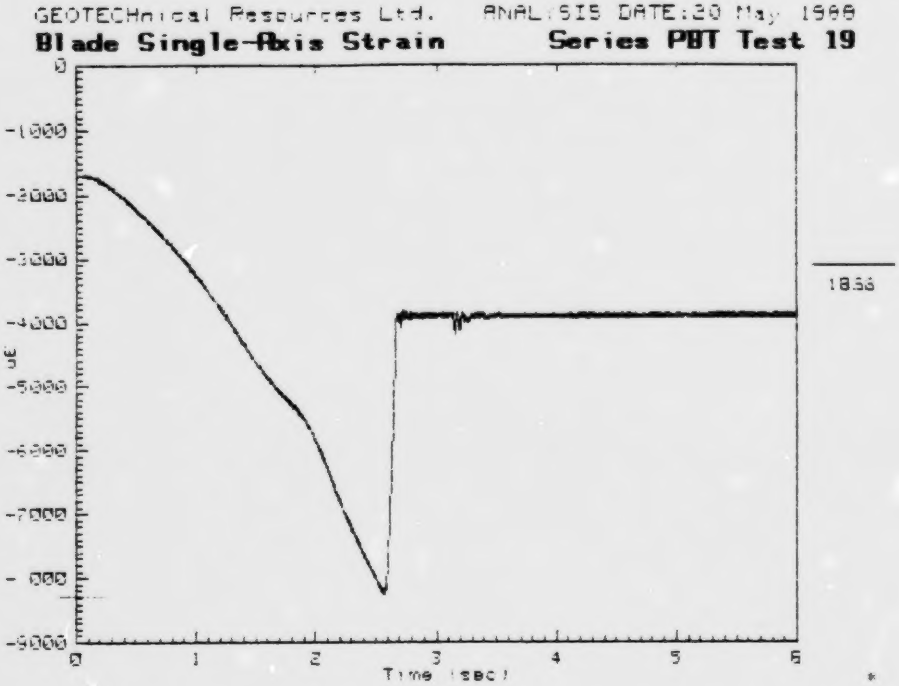
Blade Single-Axis Strain Series PBT Test 19

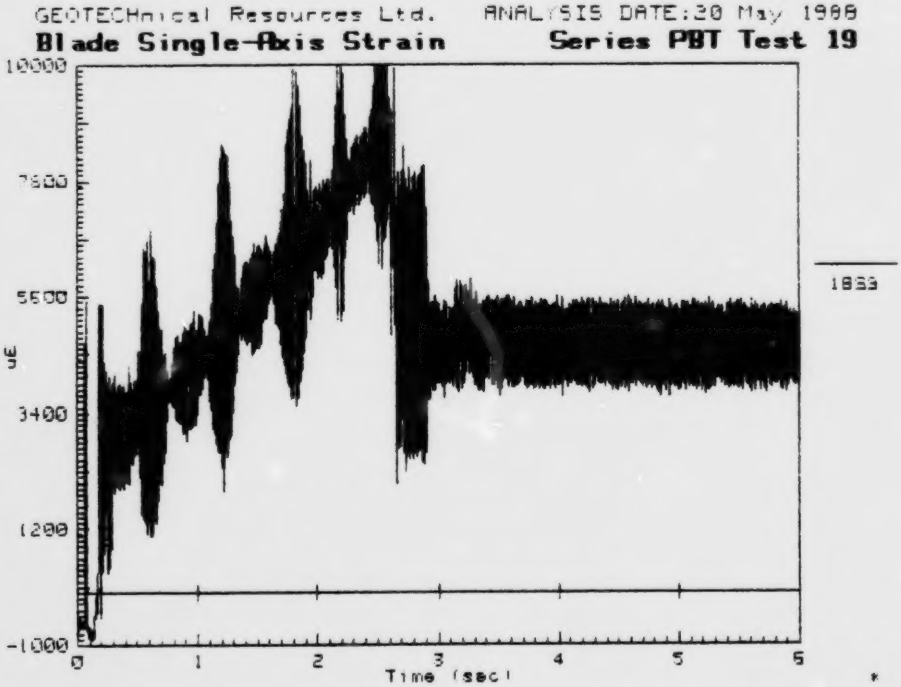


GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

Blade Single-Axis Strain Series PBT Test 19

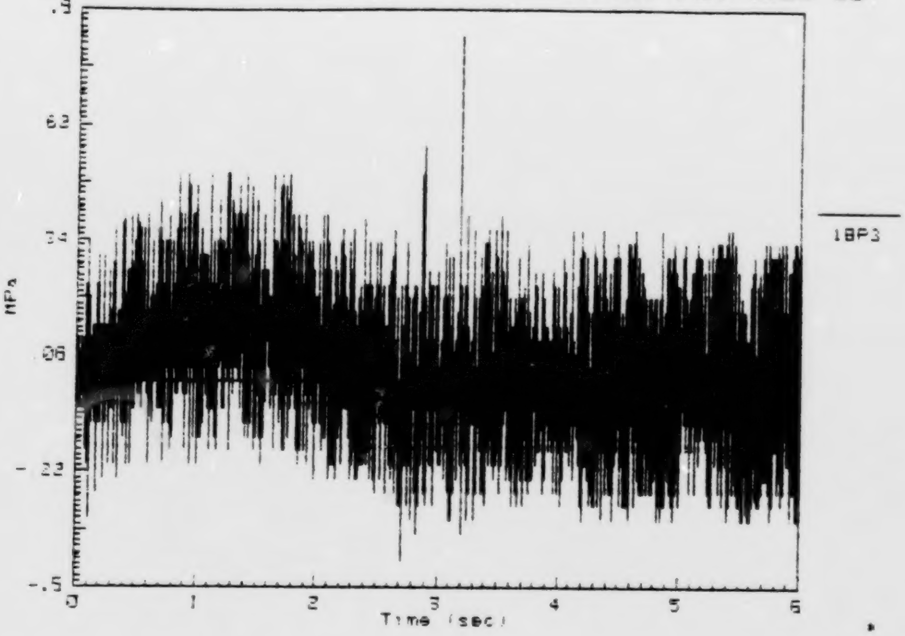



GEOTECHnical Resources Ltd.
ANALYSIS DATE:20 May 1988
Blade Single-Axis Strain
Series PBT Test 19
0
-1000
-2000
-3000
-4000
-5000
-6000
-7000
-8000
-9000
uE
0
1
2
3
4
5
6
Time (sec)
1856
*


GEOTECHnical Resources Ltd.
ANALYSIS DATE:20 May 1988
Blade Single-Axis Strain
Series PBT Test 19
10000
7800
5600
3400
1200
-1000
uE
0
1
2
3
4
5
6
Time (sec)
1853
*

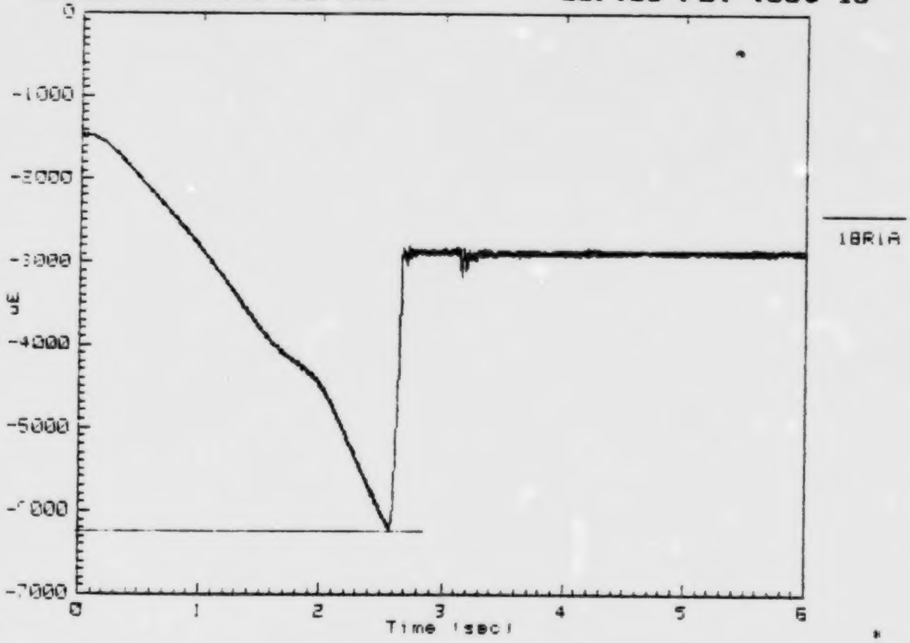
GEOTECHnical Resources Ltd.   ANALYSIS DATE:20 May 1988

Blade Surface Pressure   **Series PBT Test 19**



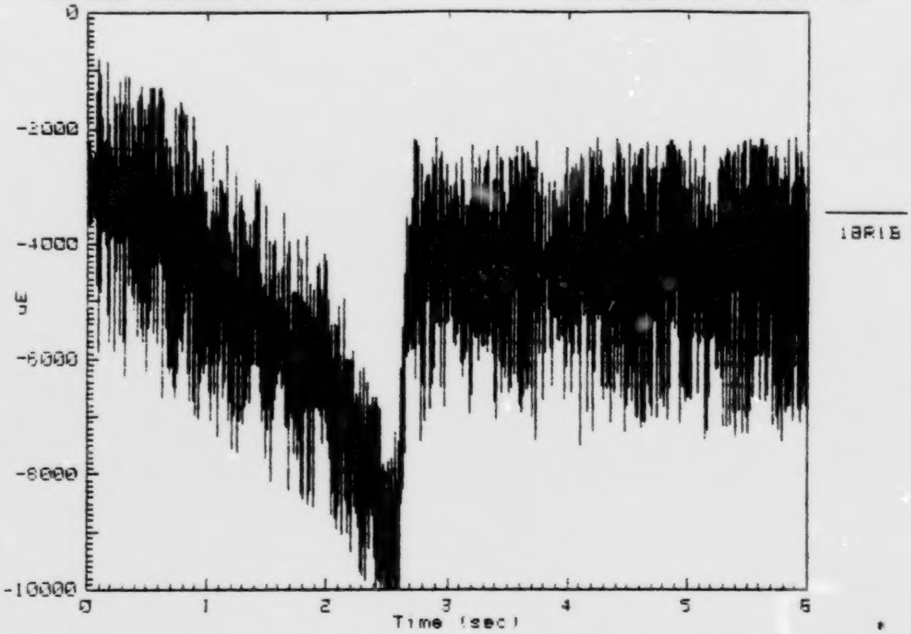
GEOTECHnical Resources Ltd.   ANALYSIS DATE:20 May 1988

Blade Rosette Strain   **Series PBT Test 19**



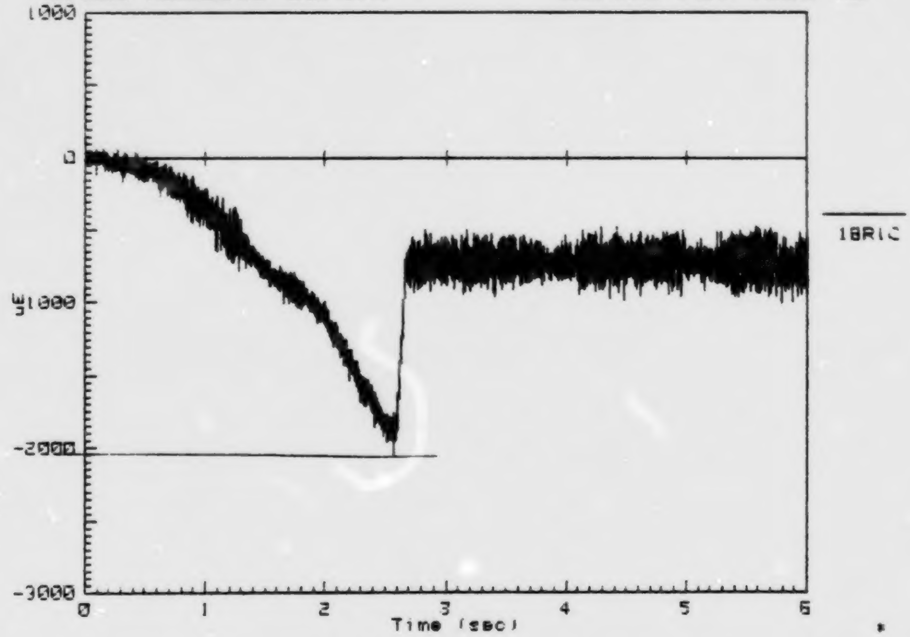
GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

Blade Rosette Strain **Series PBT Test 19**



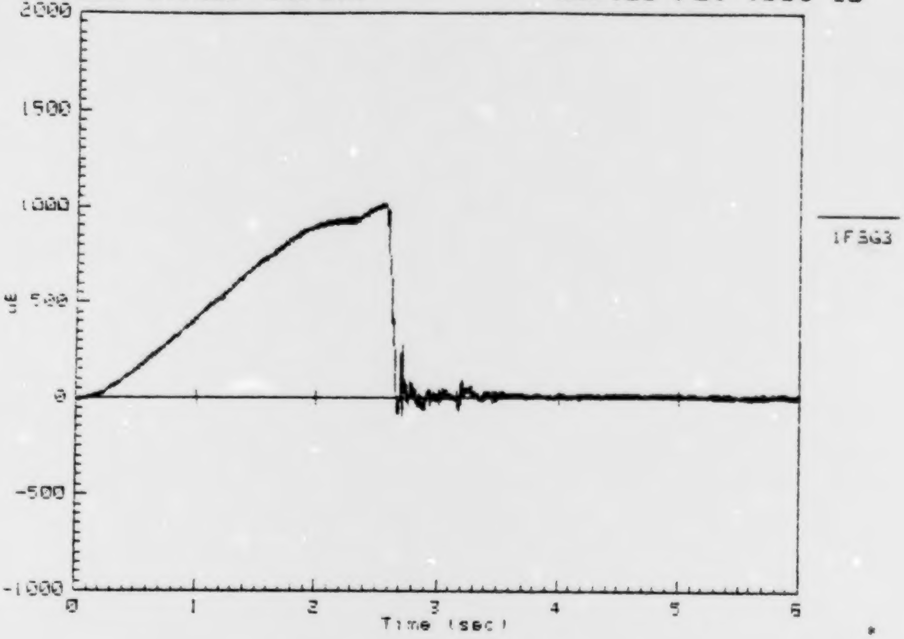
GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

Blade Rosette Strain **Series PBT Test 19**



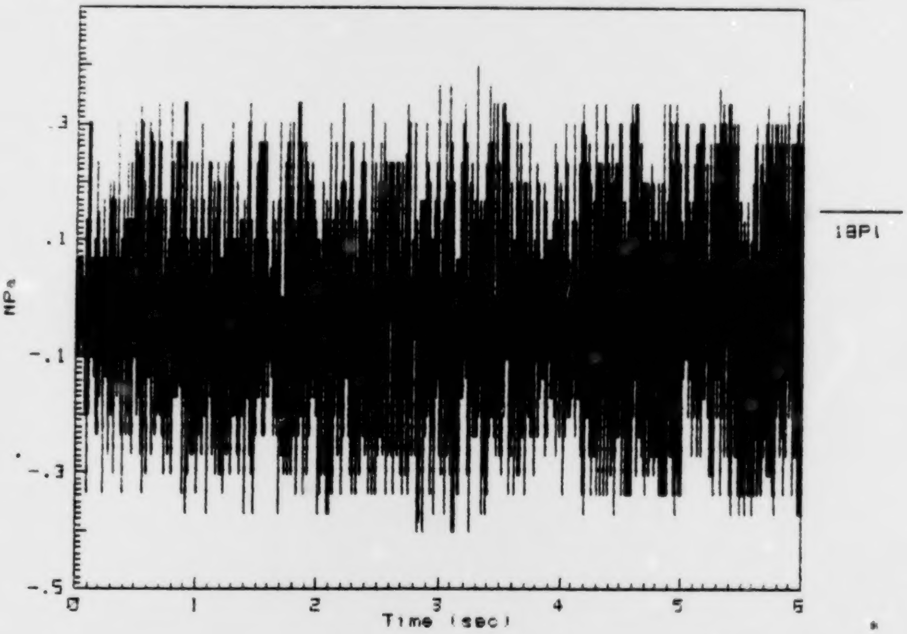
GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

Frame Girder Strain **Series PBT Test 19**

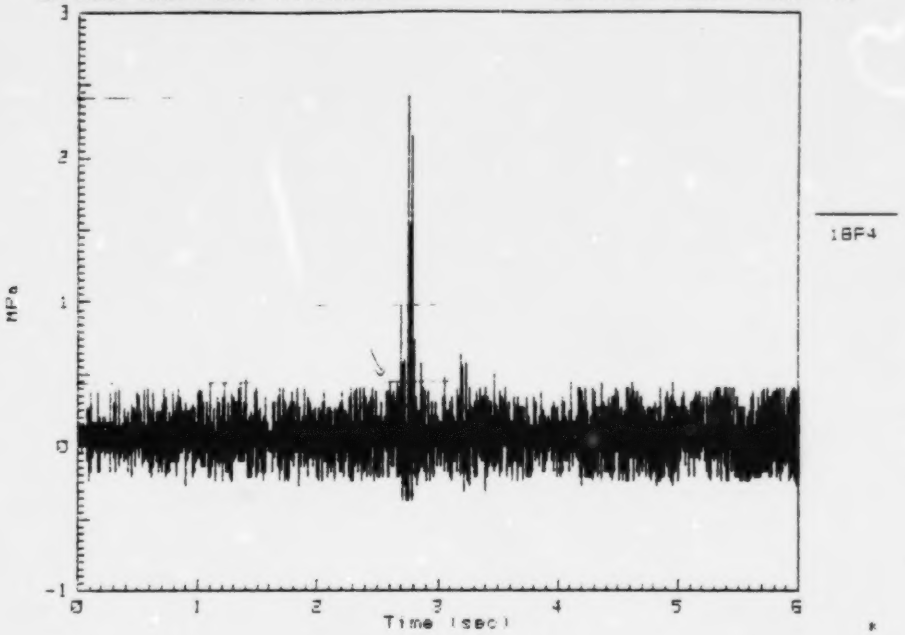


GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

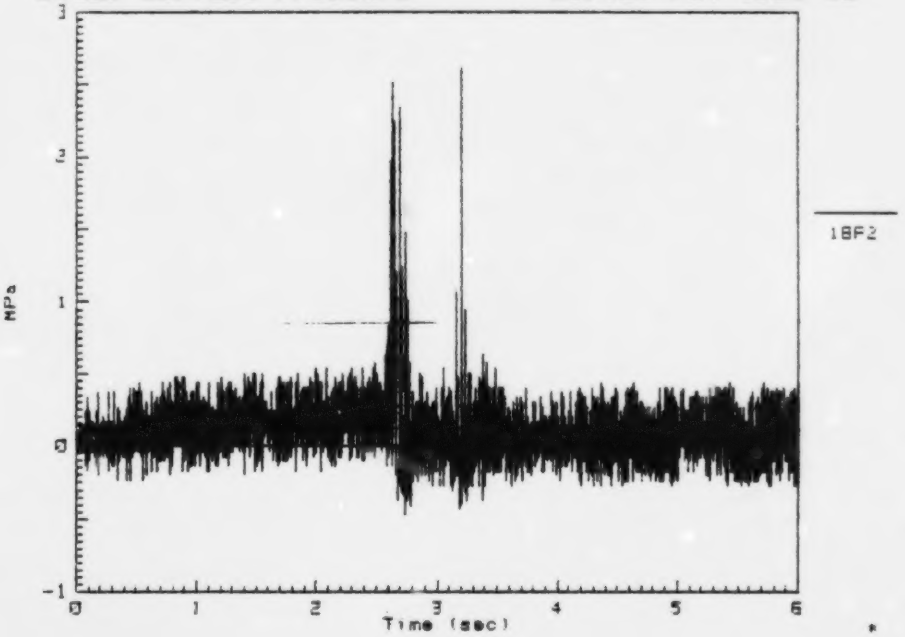
Blade Surface Pressure **Series PBT Test 19**



GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988
Blade Surface Pressure **Series PBT Test 19**

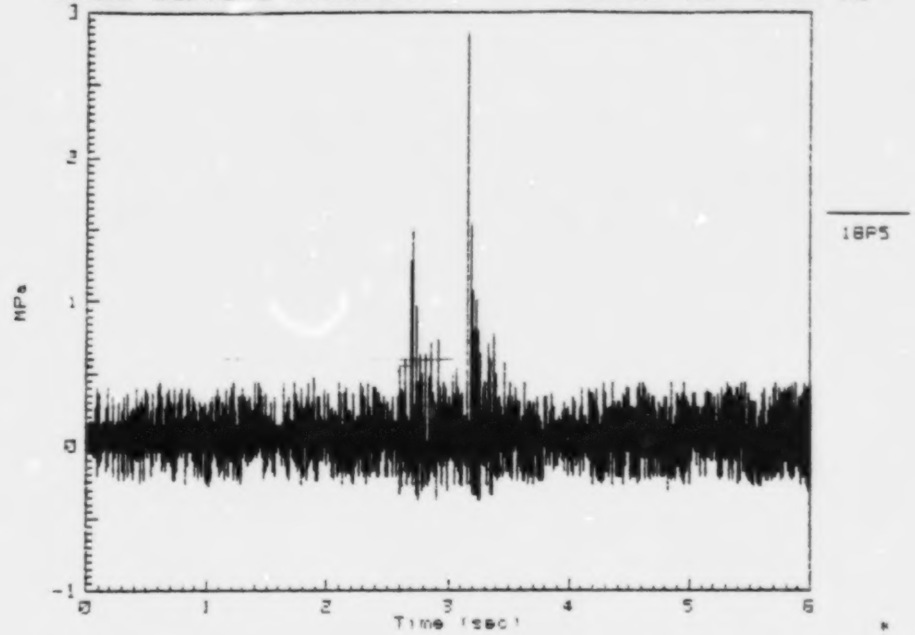


GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988
Blade Surface Pressure **Series PBT Test 19**



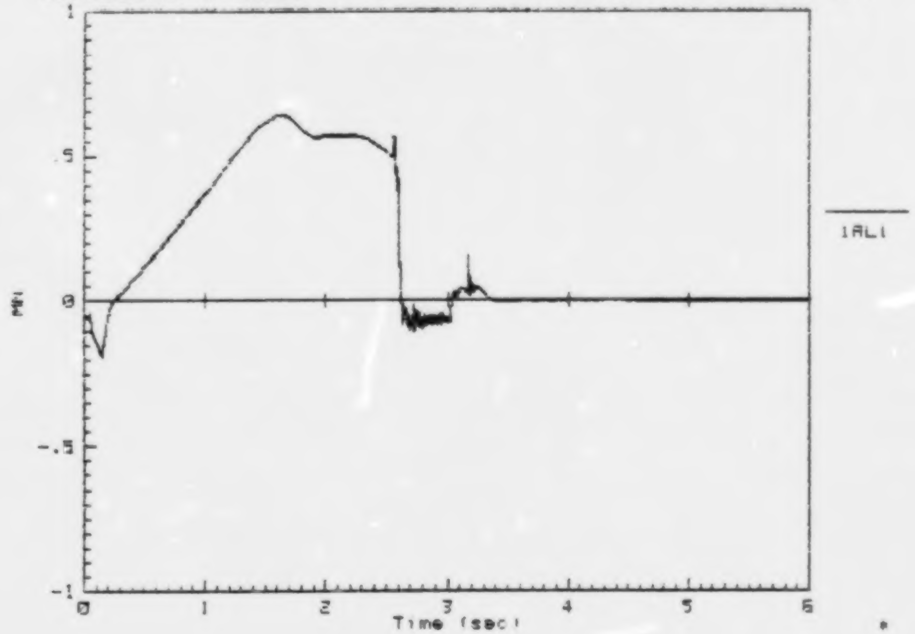
GEOTECHnical Resources Ltd.   ANALYSIS DATE:20 May 1988

Blade Surface Pressure   Series PBT Test 19



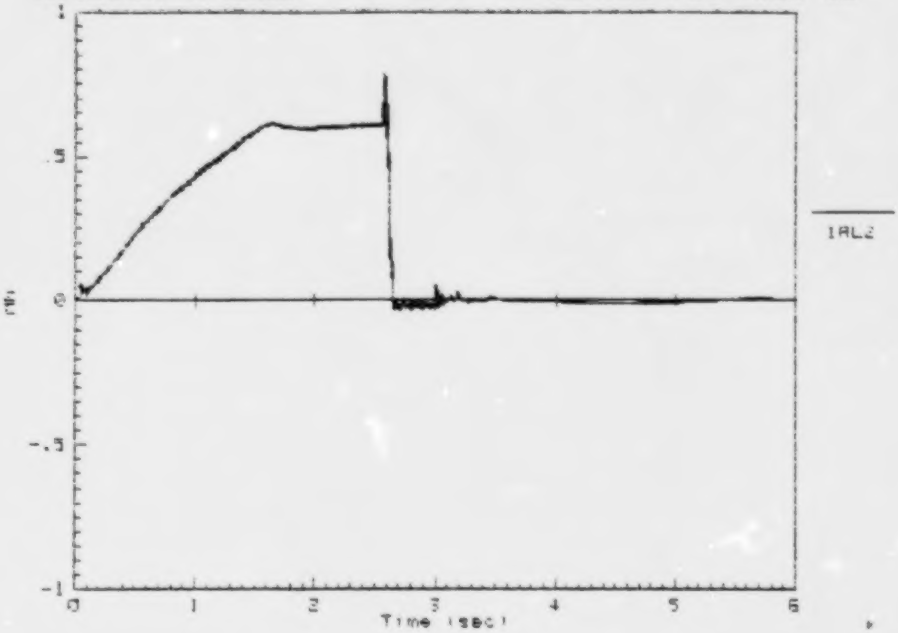
GEOTECHnical Resources Ltd.   ANALYSIS DATE:20 May 1988

Actuator 1 Load   Series PBT Test 19



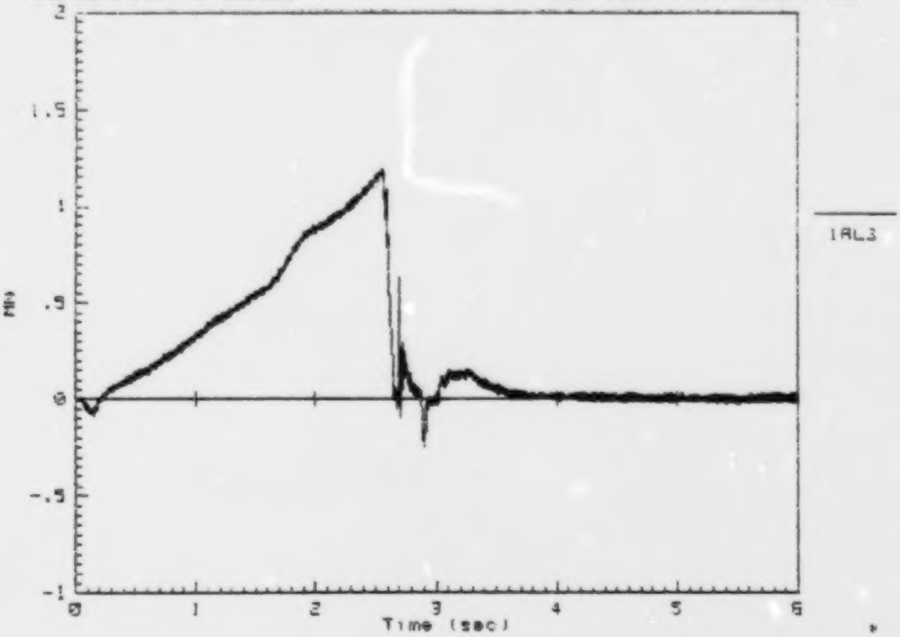
GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

Actuator 2 Load **Series PBT Test 19**



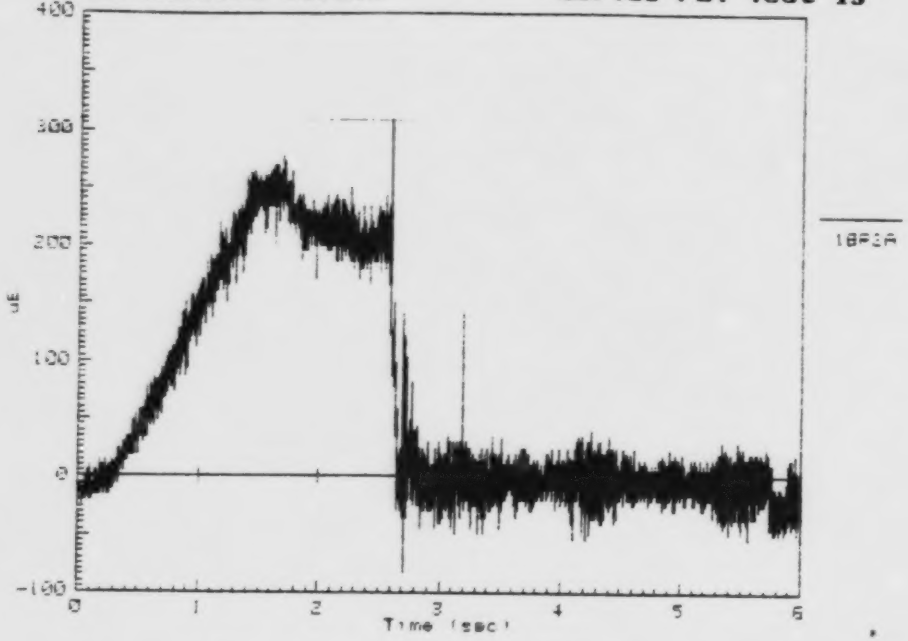
GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

Actuator 3 Load **Series PBT Test 19**



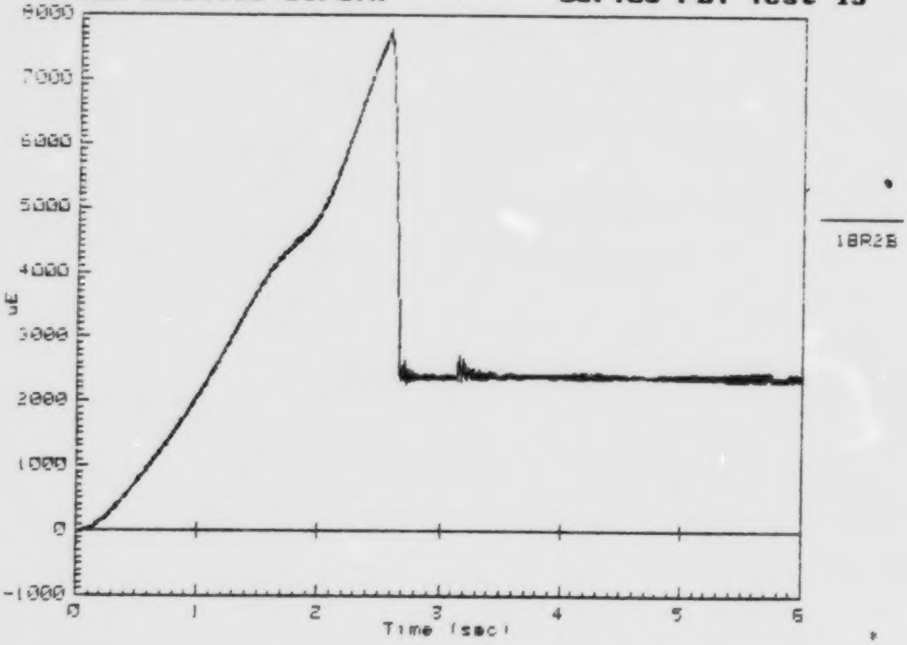
GEOTECHnical Resources Ltd.   ANALYSIS DATE:20 May 1988

Blade Rosette Strain   **Series PBT Test 19**



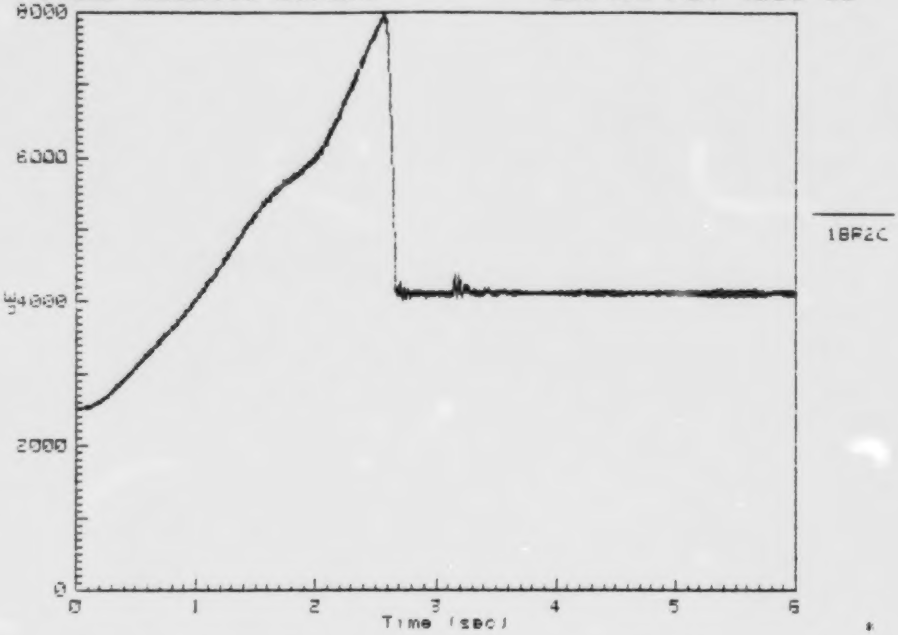
GEOTECHnical Resources Ltd.   ANALYSIS DATE:20 May 1988

Blade Rosette Strain   **Series PBT Test 19**



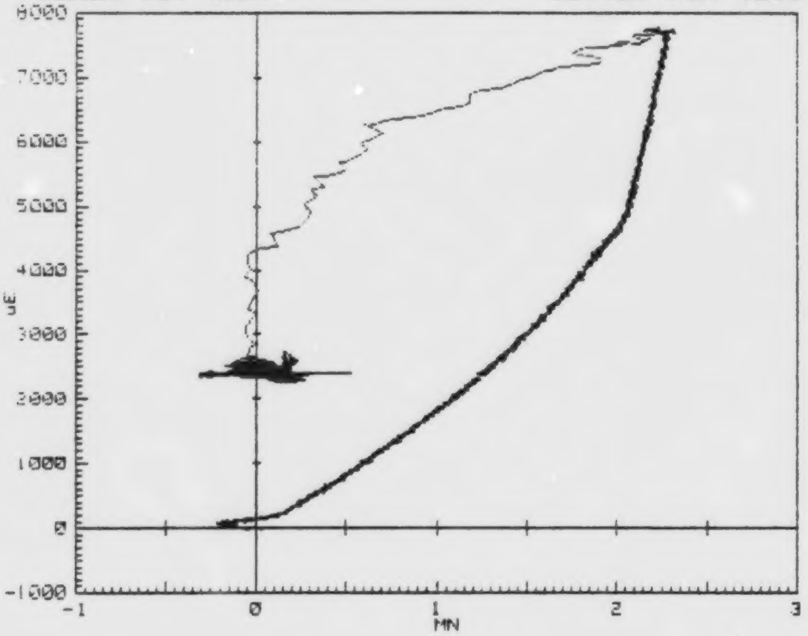
GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

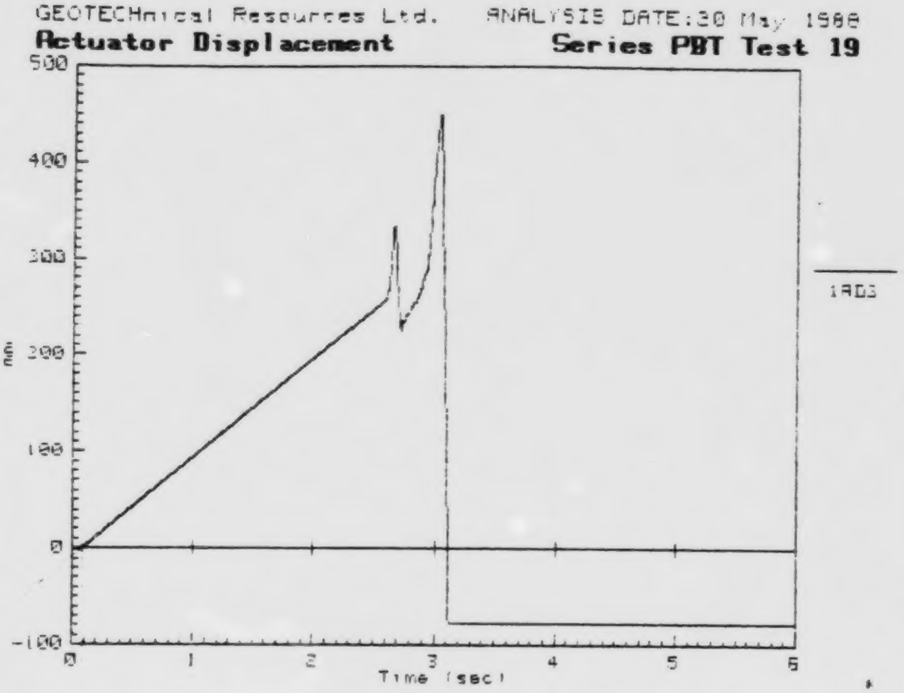
Blade Rosette Strain **Series PBT Test 19**



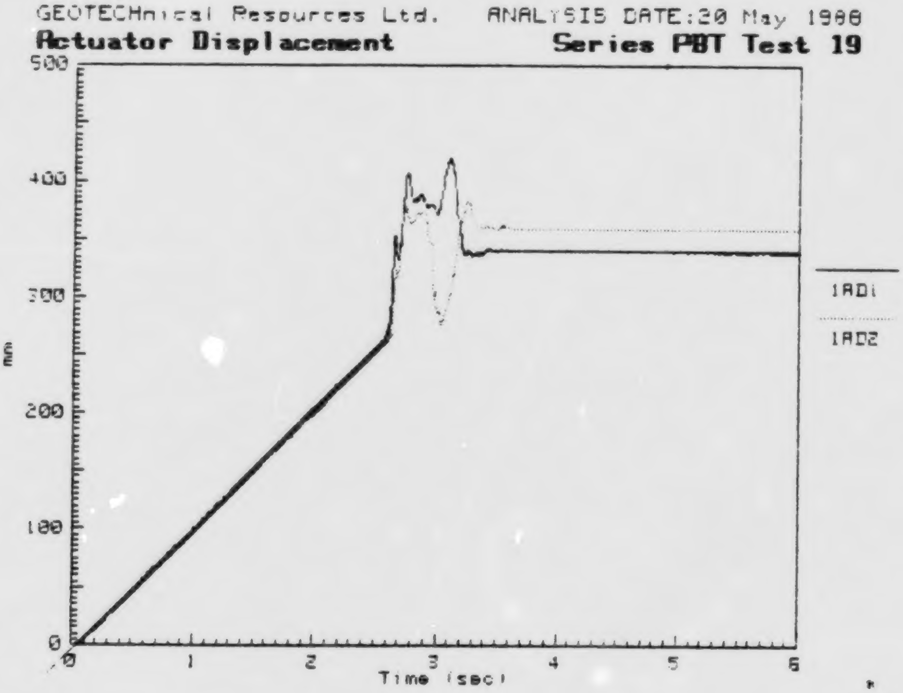
GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

1BR2B vs. 1ALT **Series PBT Test 19**

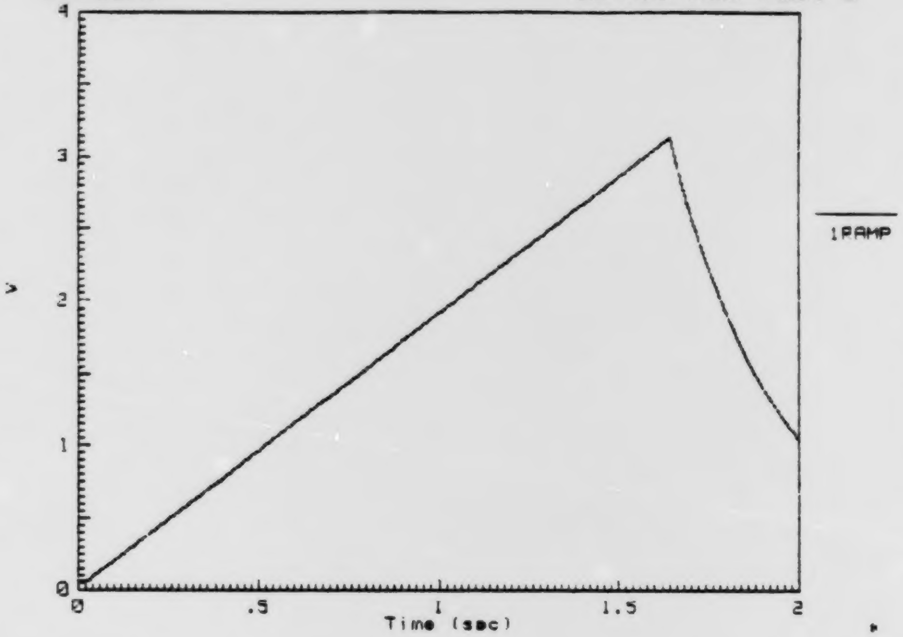


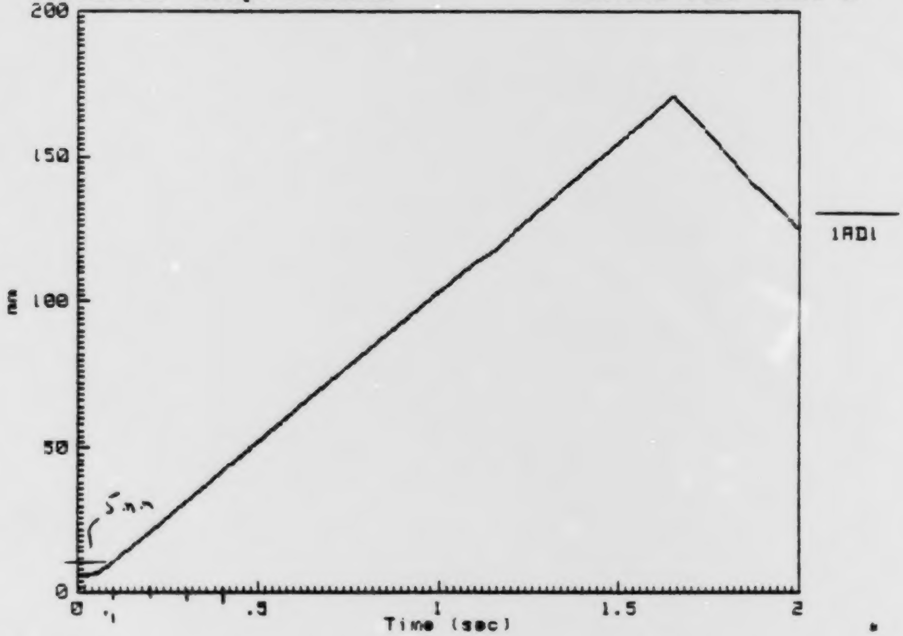


$$v \doteq \frac{500\ mm}{4.95-0.08\ s} \doteq 102.67\ \frac{mm}{s}$$



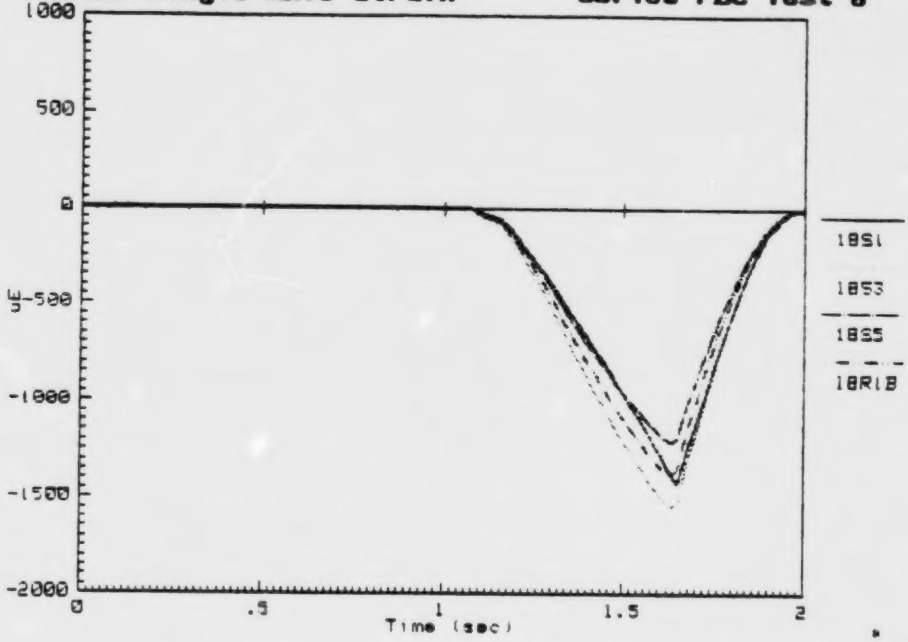
TEST COPY PROGRAM
GEOTECHnical resources ltd.


GEOTECHnical Resources Ltd. ANALYSIS DATE:28 Apr 1988
Command **Series PBC Test 6**


GEOTECHnical Resources Ltd. ANALYSIS DATE:28 Apr 1988
Actuator Displacement **Series PBC Test 6**

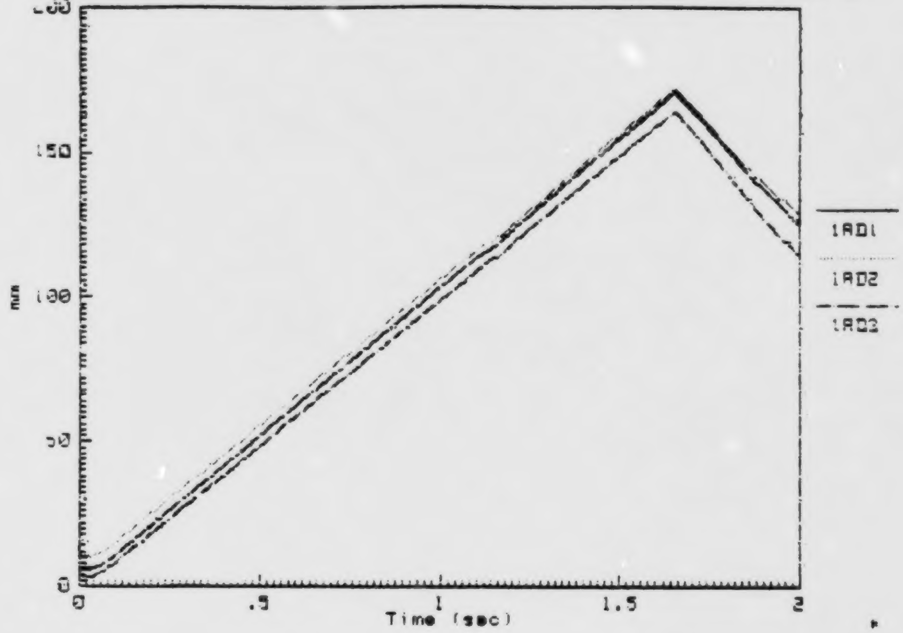
GEOTECHnical Resources Ltd. ANALYSIS DATE:28 Apr 1988

Blade Single-Axis Strain **Series PBC Test 6**



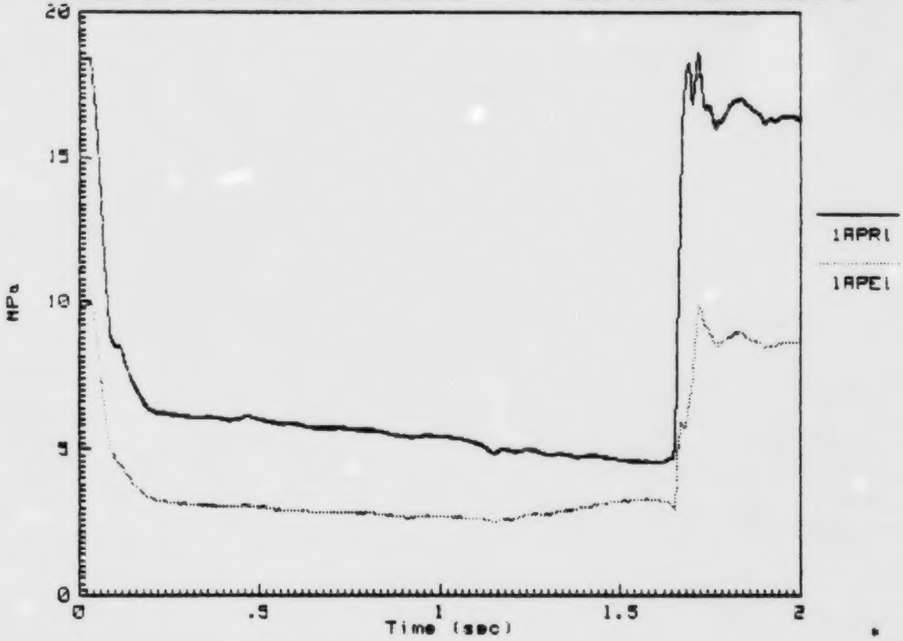
[illegible]

Actuator Displacement **Series PBC Test 6**



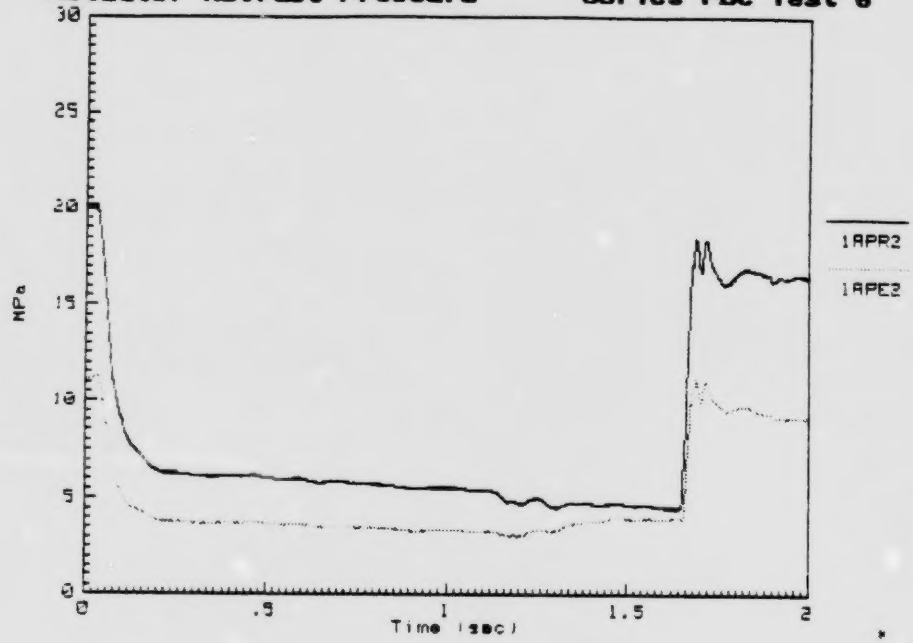
GEOTECHnical Resources Ltd. ANALYSIS DATE:29 Apr 1988

Actuator Retract Pressure **Series PBC Test 6**



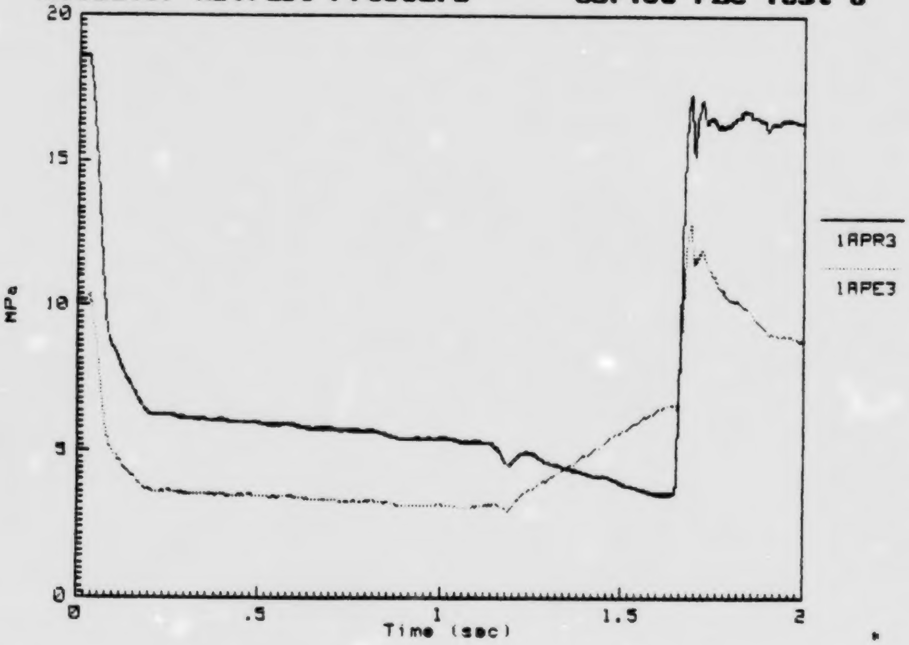
GEOTECHnical Resources Ltd.   ANALYSIS DATE:29 Apr 1988

Actuator Retract Pressure   **Series PBC Test 6**



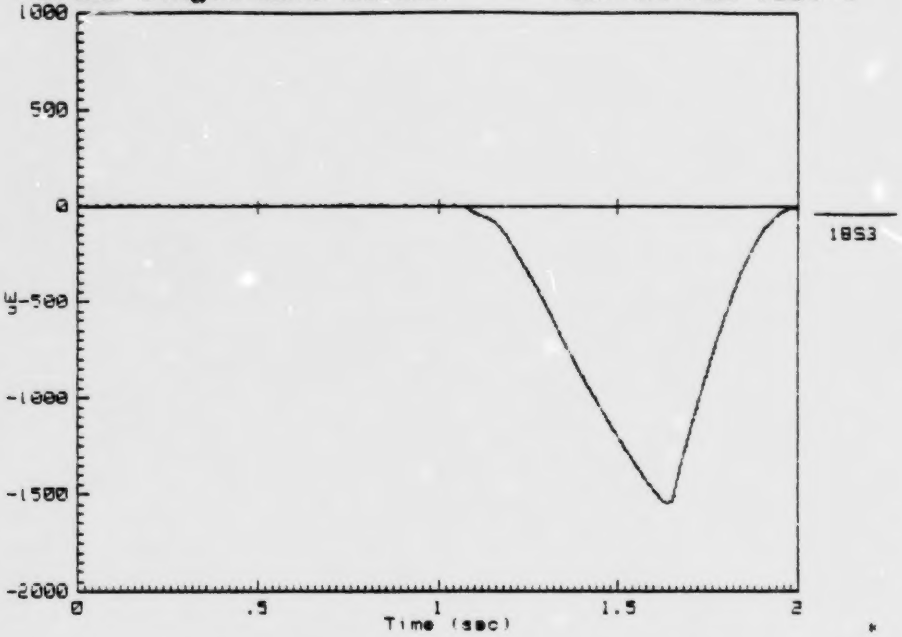
GEOTECHnical Resources Ltd.   ANALYSIS DATE:29 Apr 1988

Actuator Retract Pressure   **Series PBC Test 6**



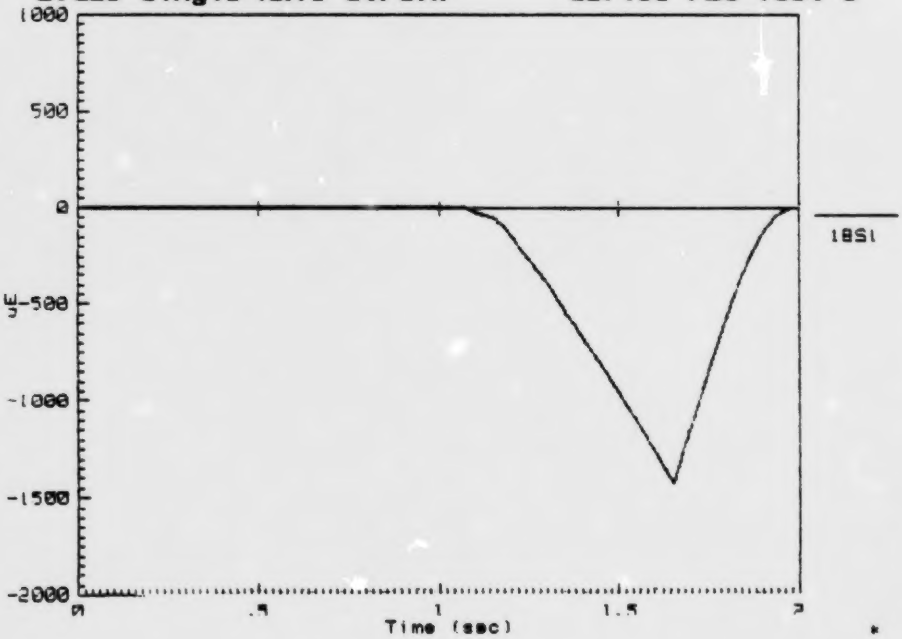
GEOTECHnical Resources Ltd.   ANALYSIS DATE:29 Apr 1988

Blade Single-Axis Strain   Series PBC Test 6



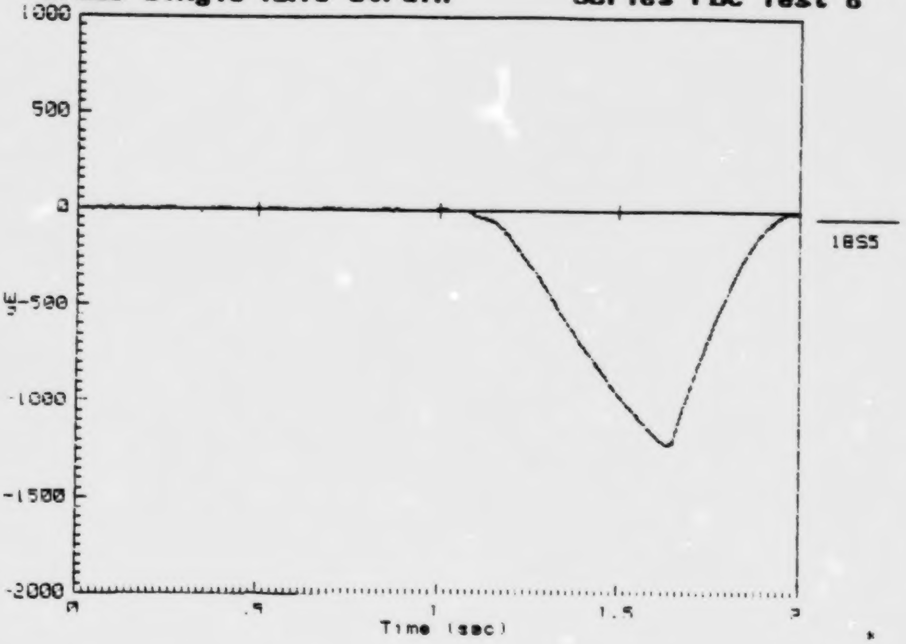
GEOTECHnical Resources Ltd.   ANALYSIS DATE:29 Apr 1988

Blade Single-Axis Strain   Series PBC Test 6



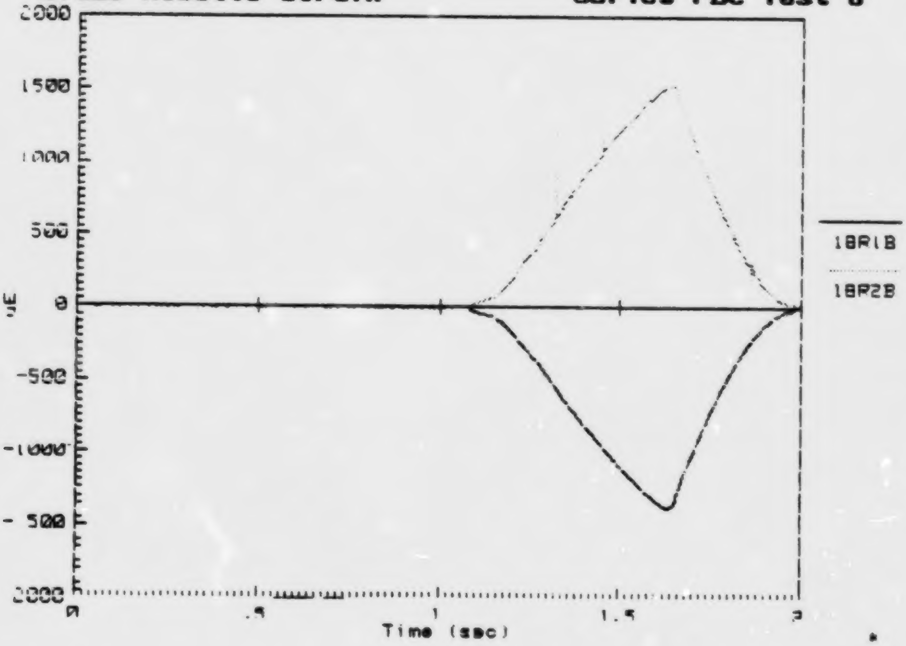
GEOTECHnical Resources Ltd. ANALYSIS DATE:29 Apr 1988

Blade Single Axis Strain **Series PDC Test 6**



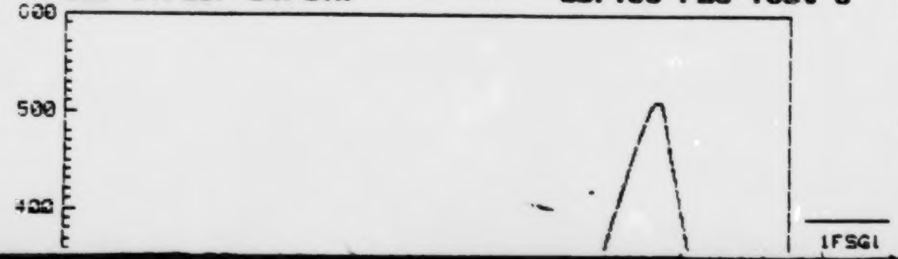
GEOTECHnical Resources Ltd. ANALYSIS DATE:29 Apr 1988

Blade Rosette Strain **Series PDC Test 6**



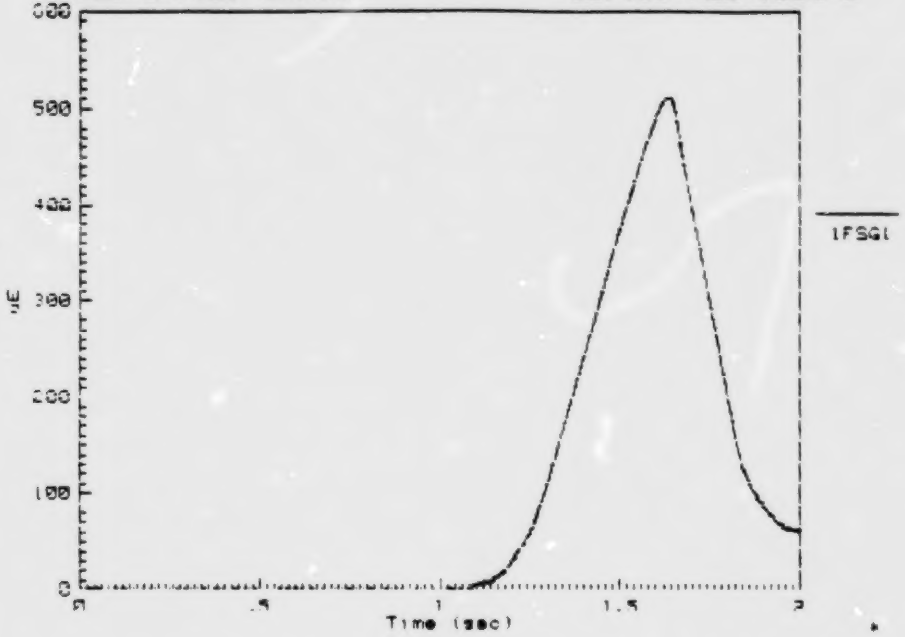
GEOTECHnical Resources Ltd. ANALYSIS DATE:29 Apr 1988

Frame Girder Strain **Series PDC Test 6**



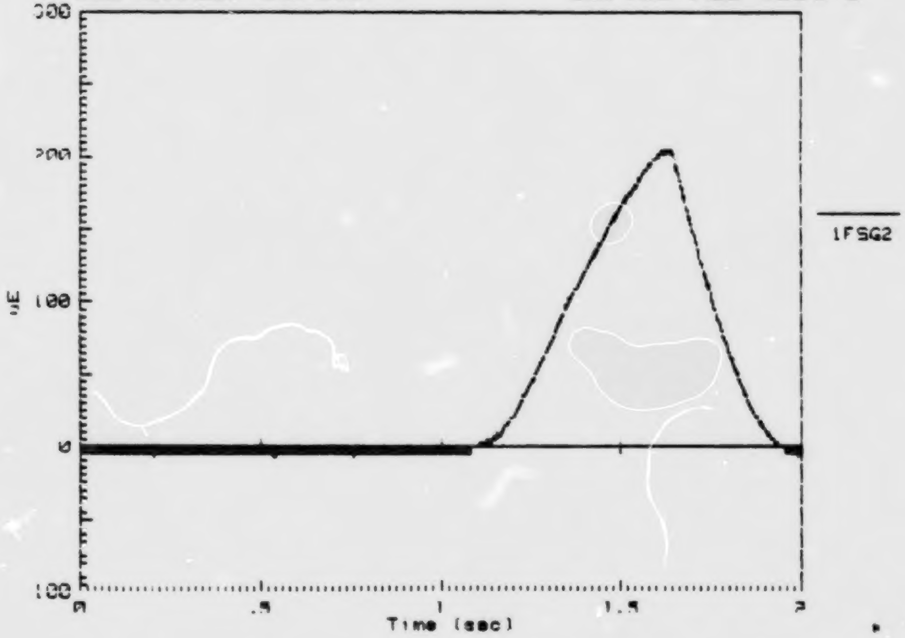
GEOTECHnical Resources Ltd.   ANALYSIS DATE:29 Apr 1988

Frame Girder Strain   Series MDC Test G



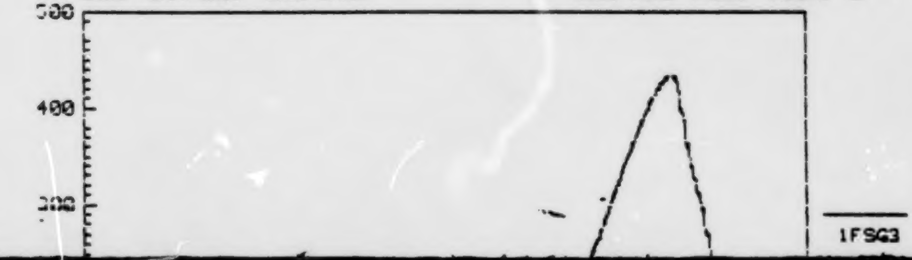
GEOTECHnical Resources Ltd.   ANALYSIS DATE:29 Apr 1988

Frame Girder Strain   Series MDC Test G



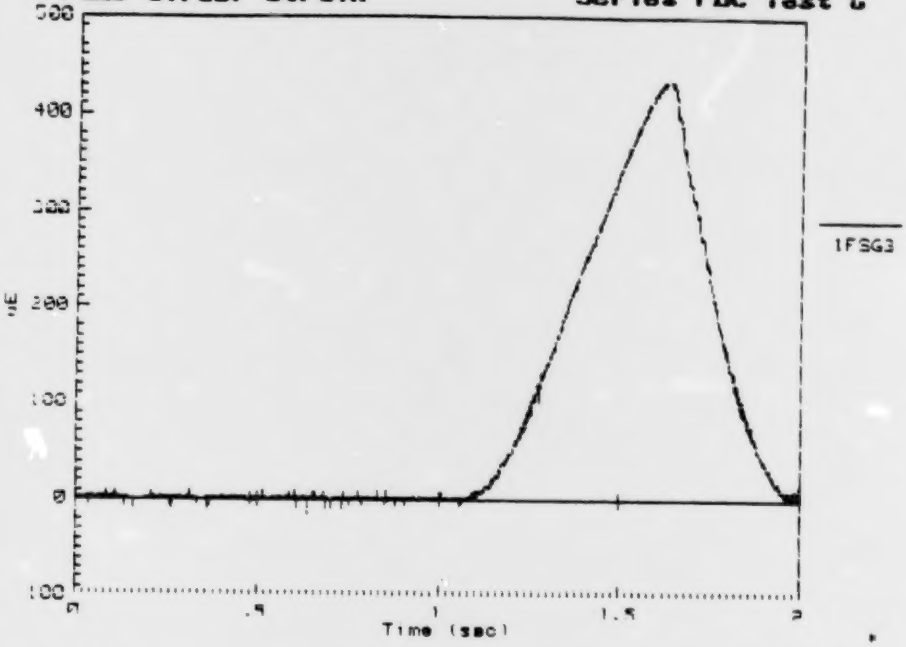
GEOTECHnical Resources Ltd.   ANALYSIS DATE:29 Apr 1988

Frame Girder Strain   Series MDC Test G



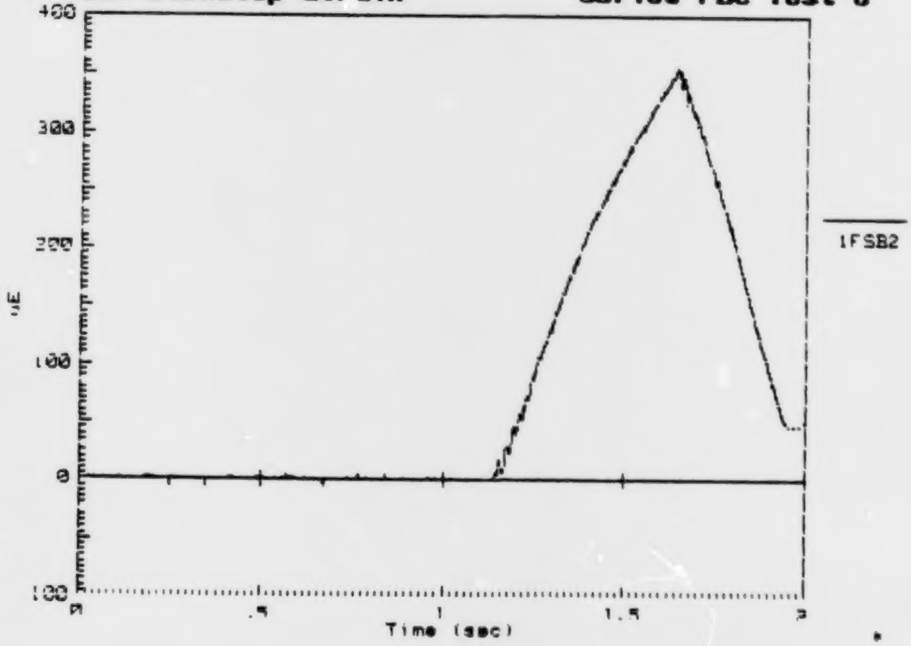
GEOTECHnical Resources Ltd.   ANALYSIS DATE:29 Apr 1988

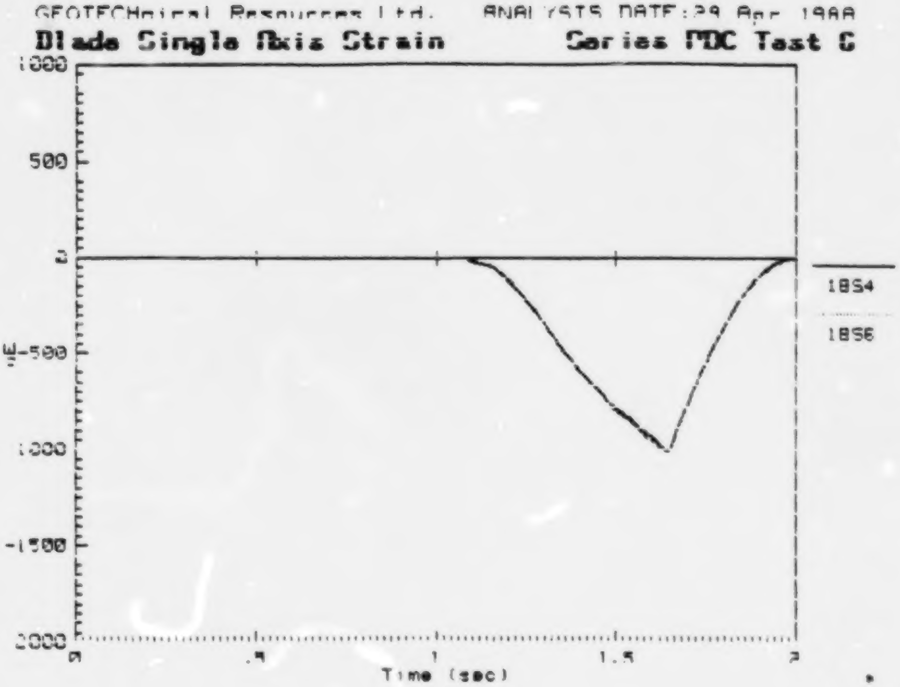
Frame Girder Strain   **Series MDC Test 6**



GEOTECHnical Resources Ltd.   ANALYSIS DATE:29 Apr 1988

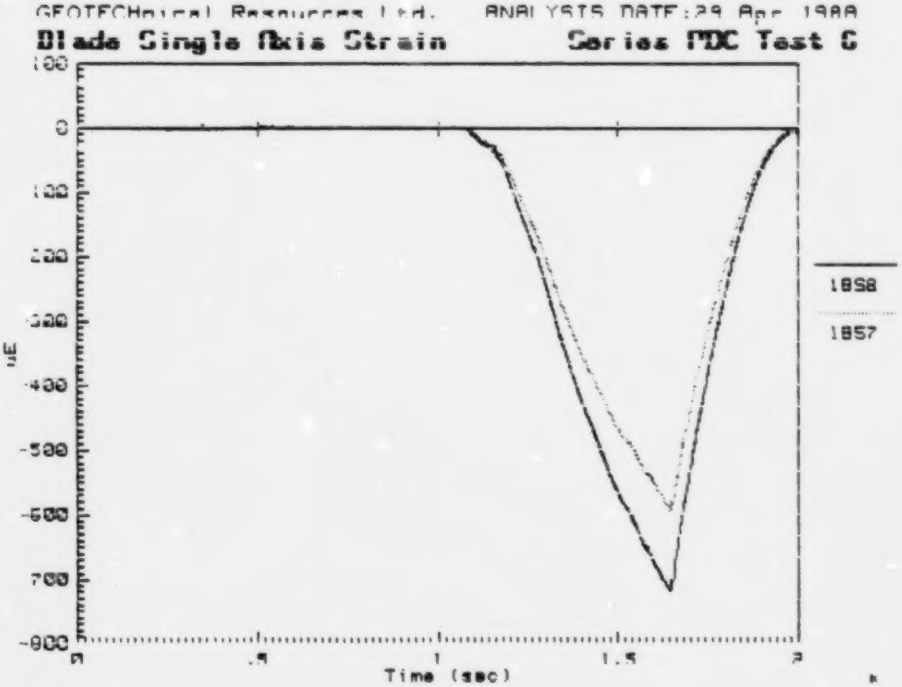
Frame Backstop Strain   **Series MDC Test 6**





GEOTECHnical Resources Ltd.   ANALYSIS DATE:29 Apr 1988

Blade Single Axis Strain   Series MDC Test 6

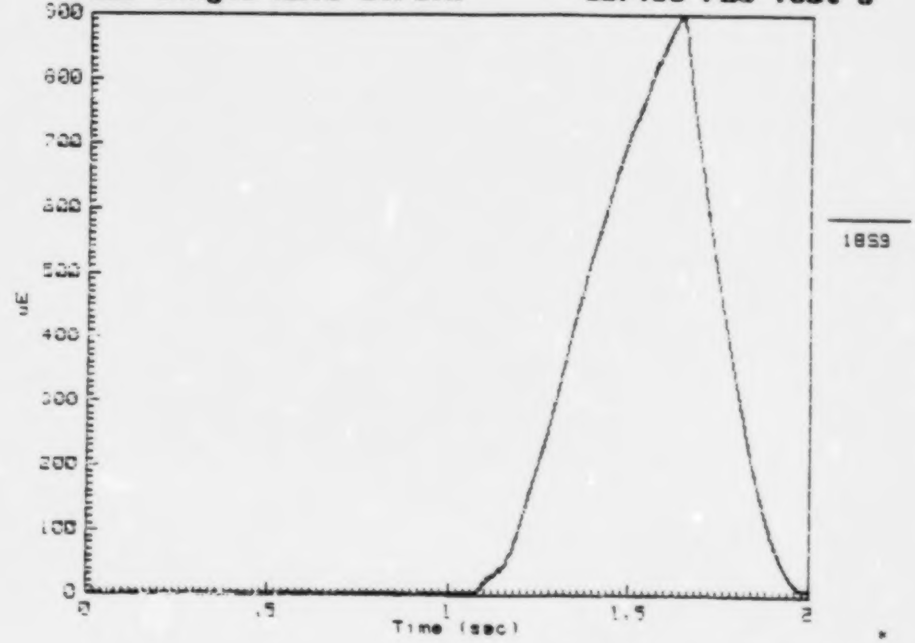


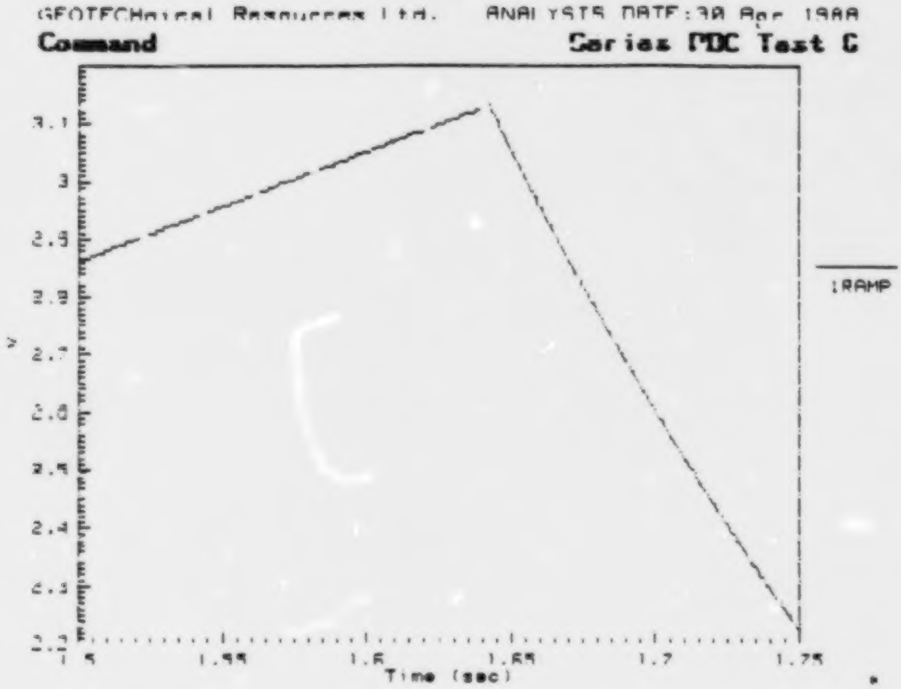
GEOTECHnical Resources Ltd.   ANALYSIS DATE:29 Apr 1988

Blade Single Axis Strain   Series MDC Test 6

GEOTECHnical Resources Ltd.   ANALYSIS DATE:29 Apr 1988

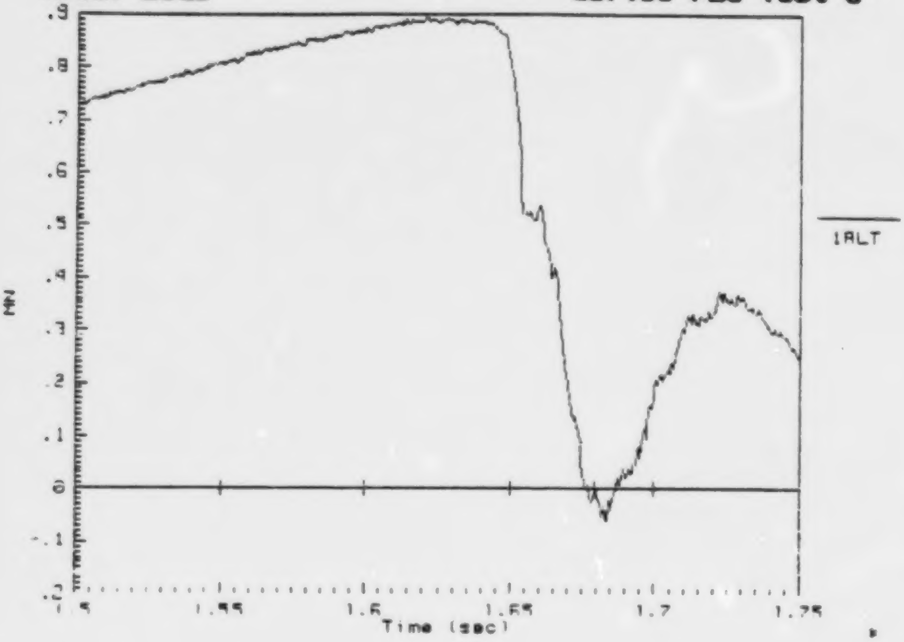
Blade Single Axis Strain   **Series PBC Test 6**




GEOTECHnical Resources Ltd.
ANALYSIS DATE:30 Apr 1988
Command
Series PDC Test C
3.1
3
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
V
1.5
1.55
1.6
1.65
1.7
1.75
Time (sec)
:RAMP

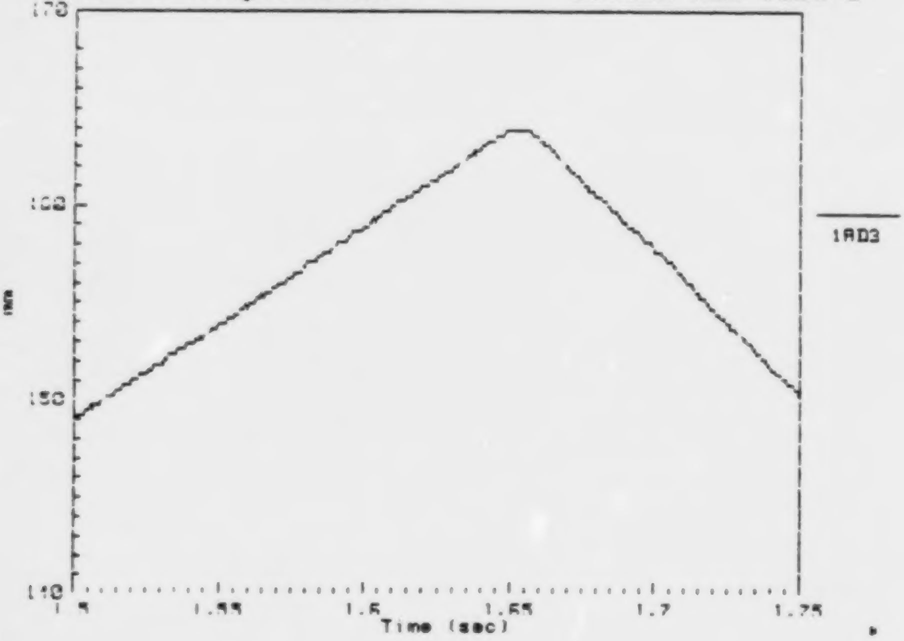
GEOTECHnical Resources Ltd. ANALYSIS DATE:30 Apr 1988

Total Load **Series PBC Test 6**



GEOTECHnical Resources Ltd. ANALYSIS DATE:30 Apr 1988

Actuator Displacement **Series PBC Test 6**



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Initializing a RAMdisk of  250000  bytes for the buffer files.
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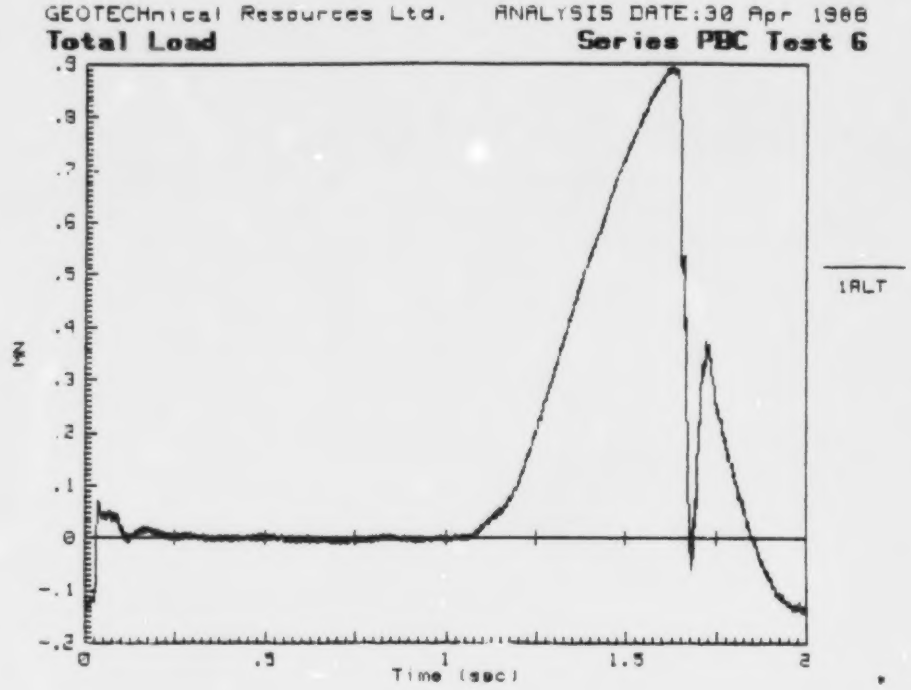
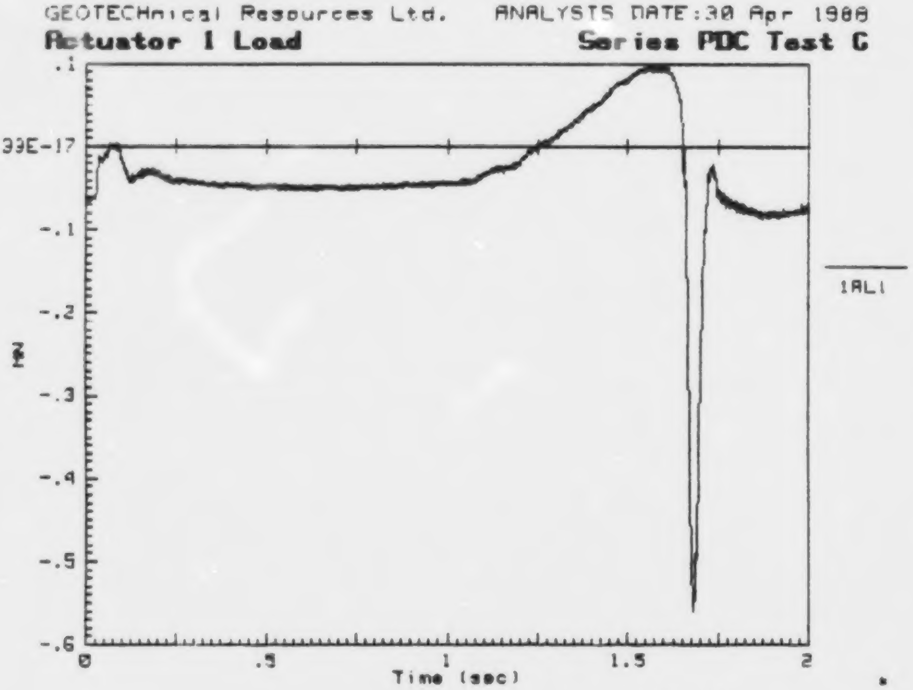


GEOTECHnical Resources Ltd.   ANALYSIS DATE:30 Apr 1988

Total Load **Series PBC Test 6**

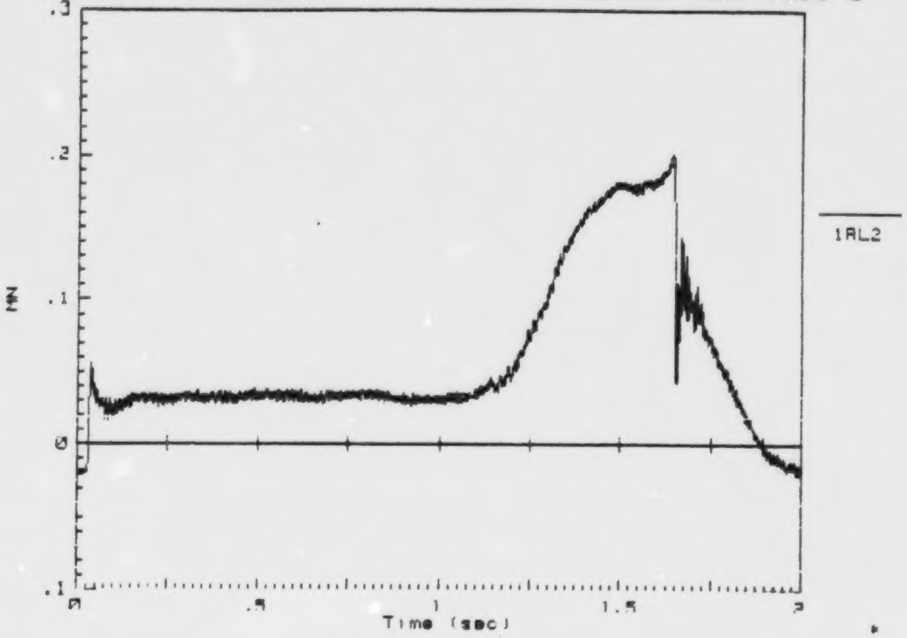


GEOTECHnical Resources Ltd.   ANALYSIS DATE:30 Apr 1988

Actuator 1 Load **Series PBC Test 6**

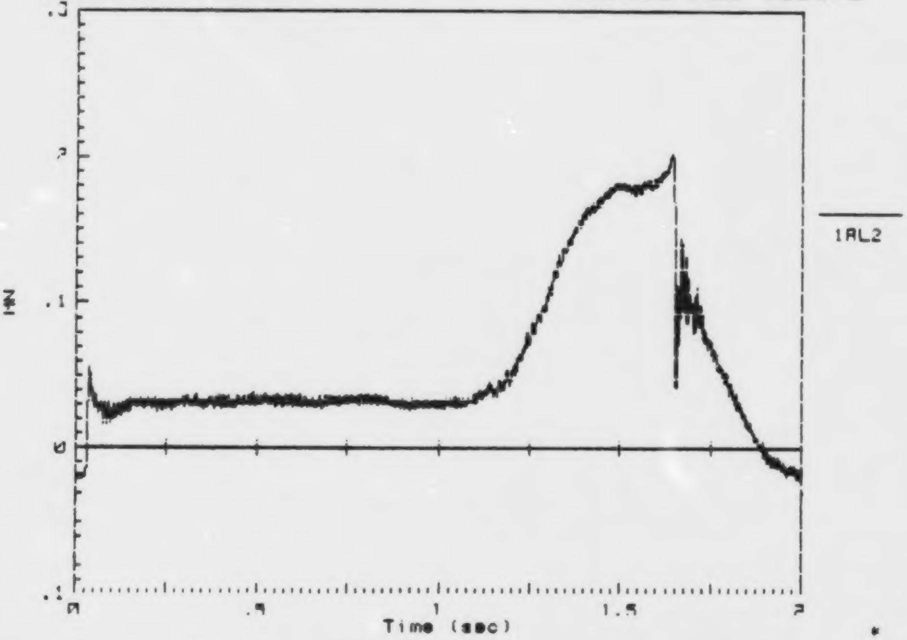
GEOTECHnical Resources Ltd. ANALYSIS DATE:30 Apr 1988

Actuator 2 Load **Series PBC Test 6**



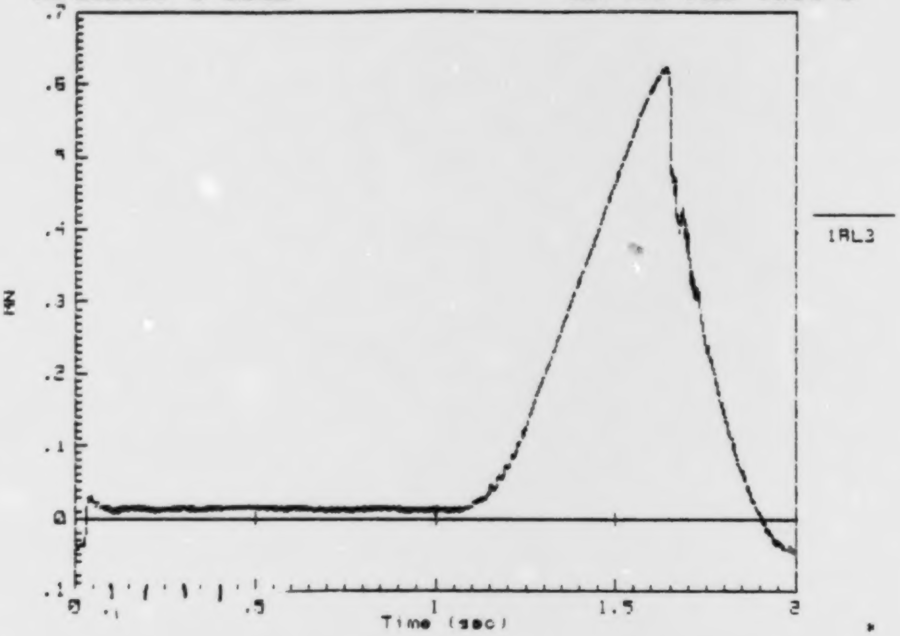
GEOTECHnical Resources Ltd. ANALYSIS DATE:30 Apr 1988

Actuator 2 Load **Series PBC Test 6**



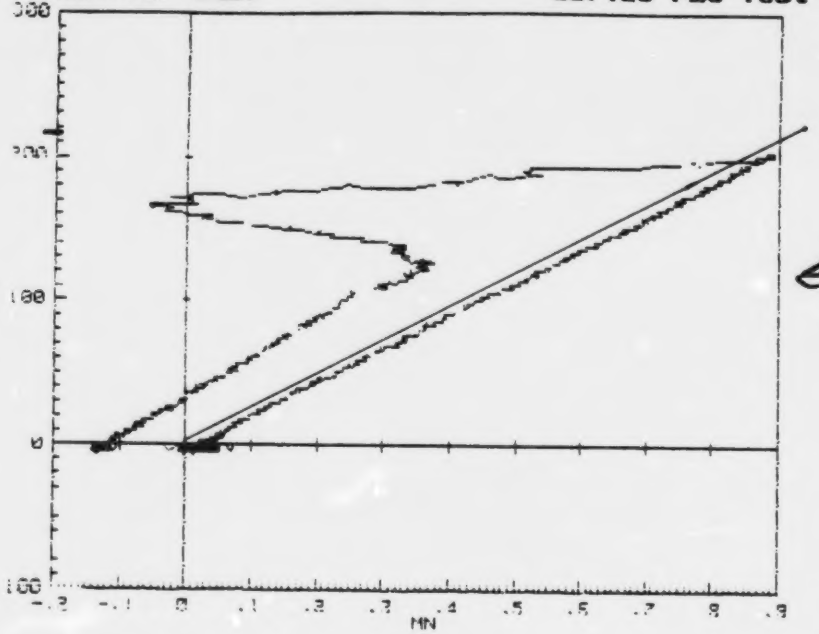
GEOTECHnical Resources Ltd.   ANALYSIS DATE:30 Apr 1988

Actuator 3 Load   **Series MDC Test G**



GEOTECHnical Resources Ltd. ANALYSIS DATE:30 Apr 1988

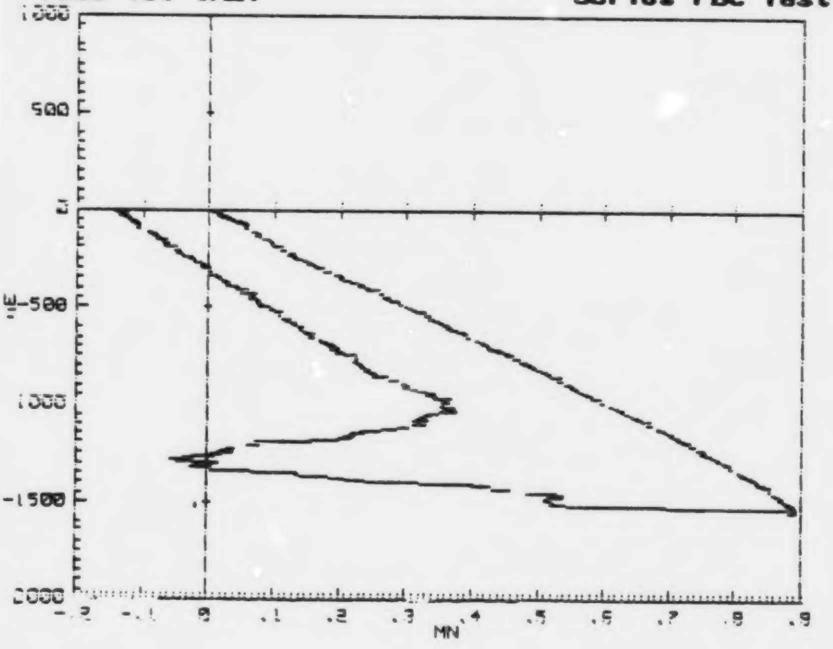
1FSG2 vs. 1MLT **Series MDC Test C**



Theory says
378με 117N
at 0.9MN
- self weight
contribution (~10με)
M.S [illegible] 3 May

GEOTECHnical Resources Ltd. ANALYSIS DATE:30 Apr 1988

1BG3 vs. 1MLT **Series MDC Test C**



APPENDIX A.7

Fourier Transform of Blade Hammer Tests

7.0 FOURIER TRANSFORM OF BLADE HAMMER TESTS

Tests PBT16 and PBT17 were conducted to determine the frequencies of the natural mode of vibration of the blade. Due to the high stiffness of the blade only small blade strains and deflections were produced with the "hand held" impact device. Good results were however obtained from the blade strain gauge 1BS1. The gauge is located on the blade centre line 598mm from the blade tip. The frequencies occurring in the blade response from 1BS1 are provided in the following table. An asterix indicates the dominant frequencies.

Table A.7.1

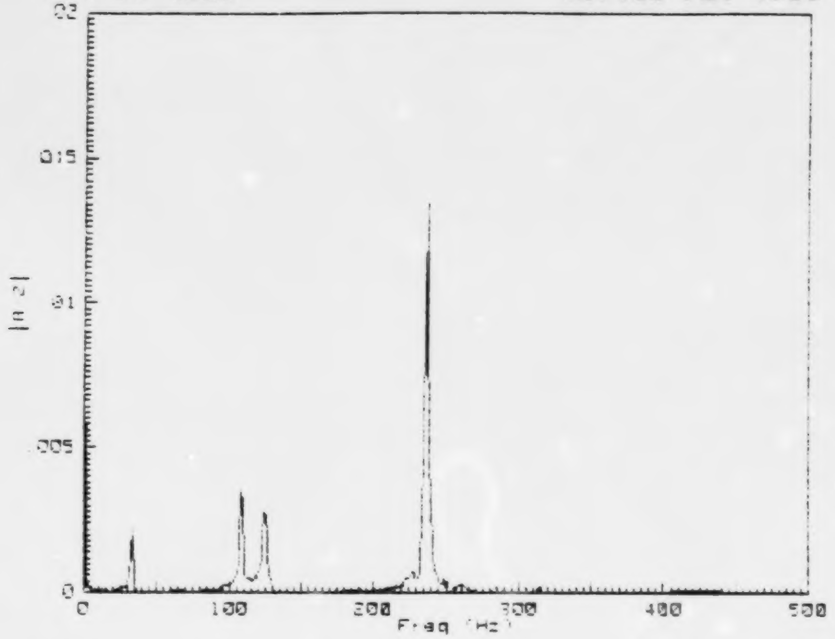
Blade Resonant Frequencies (Hz)

Test PBT16	Test PBT17
32	32
109	109*
125	237
237*	

* Dominant frequency

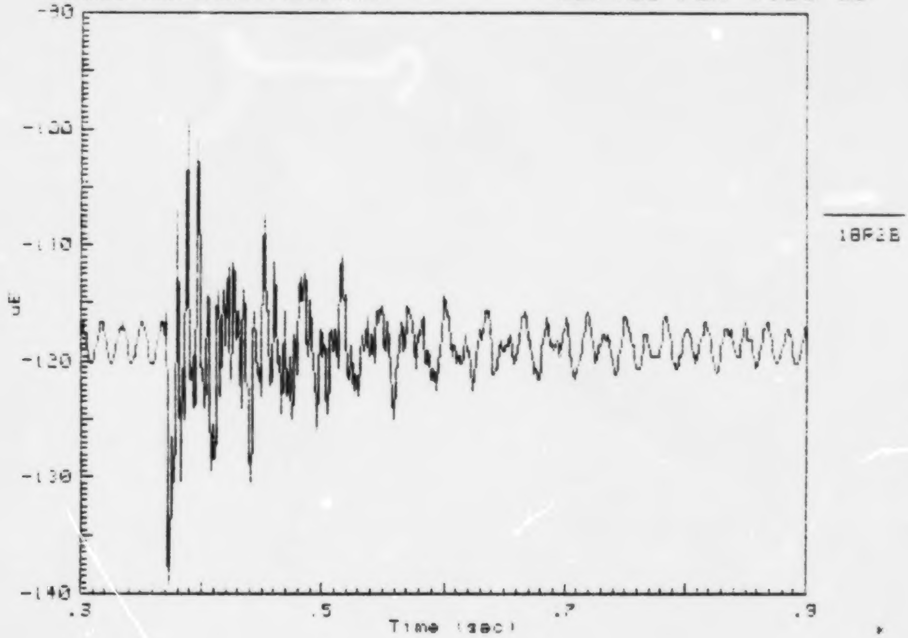
GEOTECHnical Resources Ltd.   ANALYSIS DATE:27 Sep 1988

FFT of 1BS1   **Series PBT Test 16**



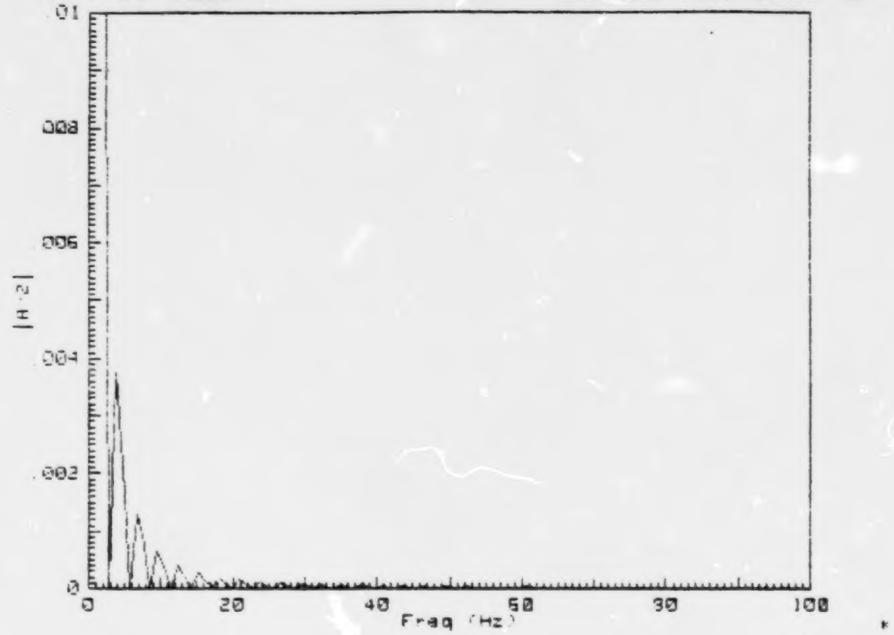
GEOTECHnical Resources Ltd.   ANALYSIS DATE:27 Sep 1988

Blade Rosette Strain   **Series PBT Test 16**



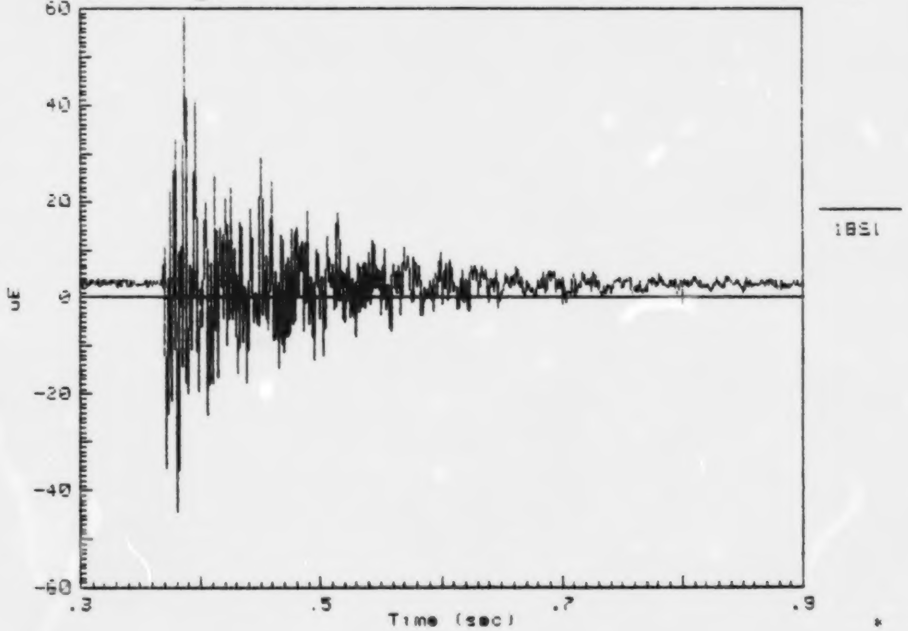
GEOTECHnical Resources Ltd. ANALYSIS DATE:27 Sep 1988

FFT of 1BD3 **Series PBT Test 16**



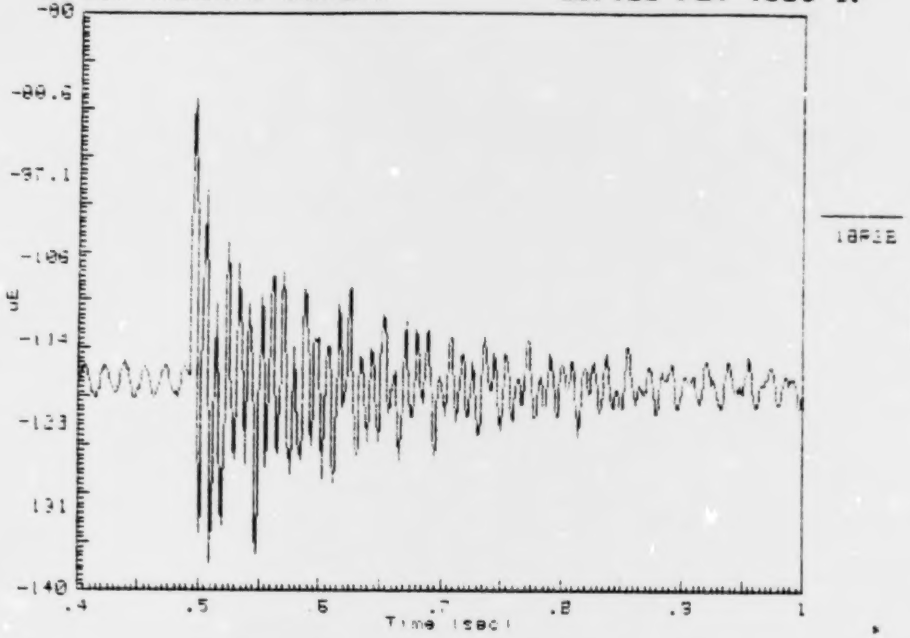
GEOTECHnical Resources Ltd. ANALYSIS DATE:27 Sep 1988

Blade Single-Axis Strain **Series PBT Test 16**



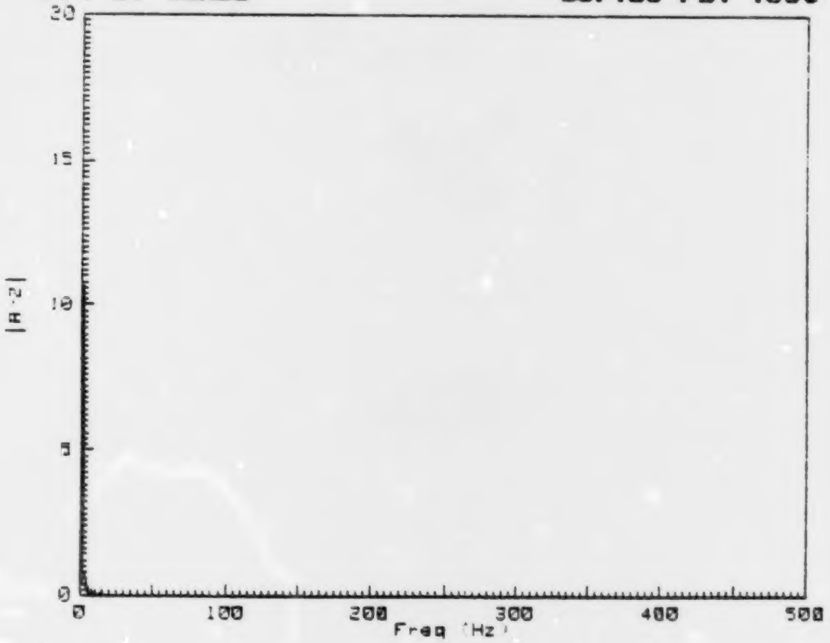
GEOTECHnical Resources Ltd.   ANALYSIS DATE:27 Sep 1988

Blade Rosette Strain   **Series PBT Test 17**



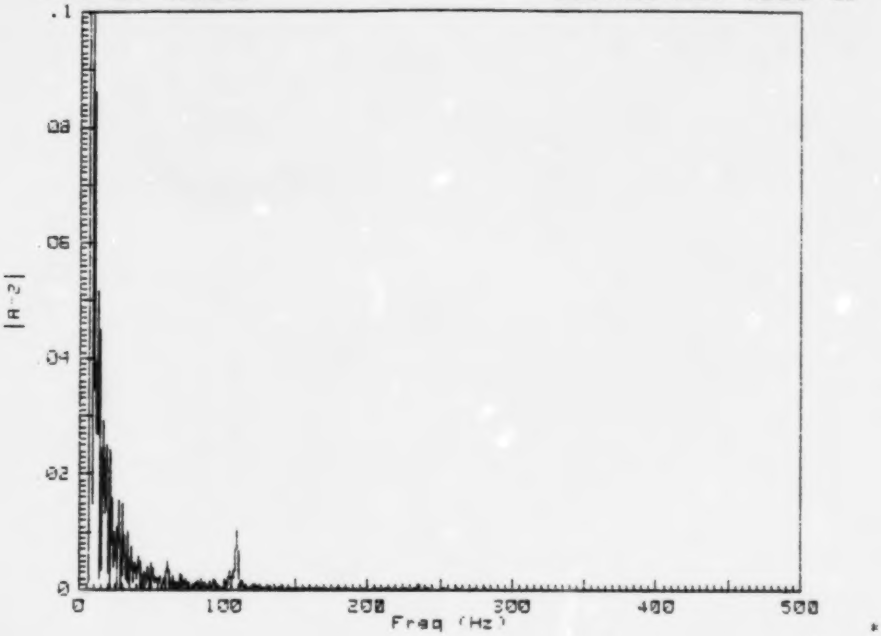
GEOTECHnical Resources Ltd.   ANALYSIS DATE:27 Sep 1988

FFT of 1BR2B   **Series PBT Test 17**



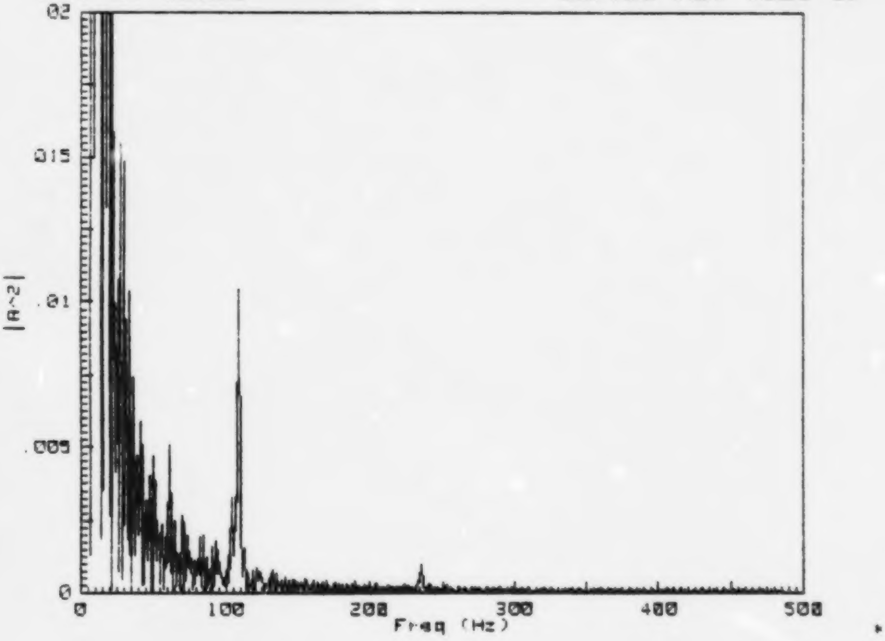
GEOTECHnical Resources Ltd.   ANALYSIS DATE:27 Sep 1988

FFT of 1BR2B   Series PBT Test 17



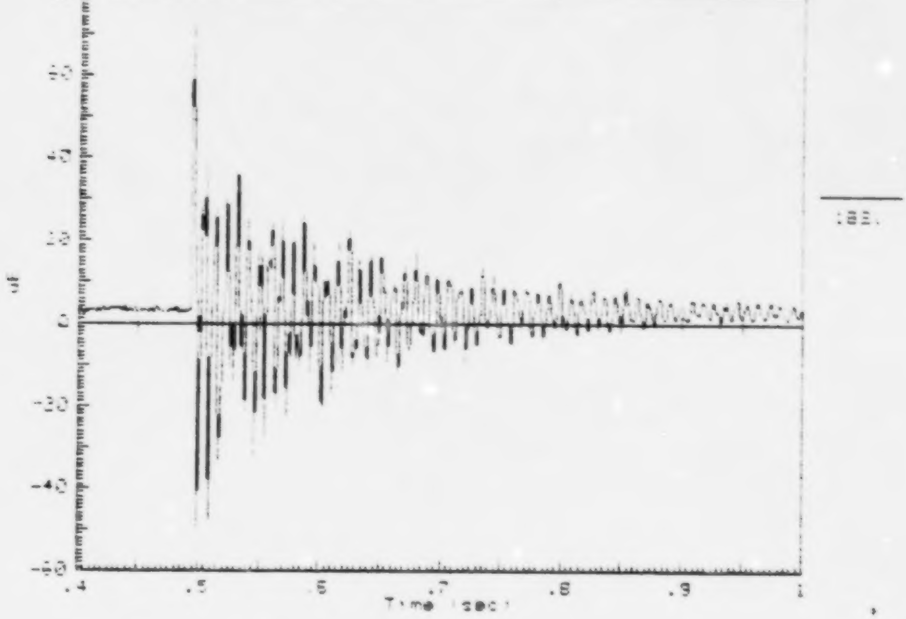
GEOTECHnical Resources Ltd.   ANALYSIS DATE:27 Sep 1988

FFT of 1BR2B   Series PBT Test 17



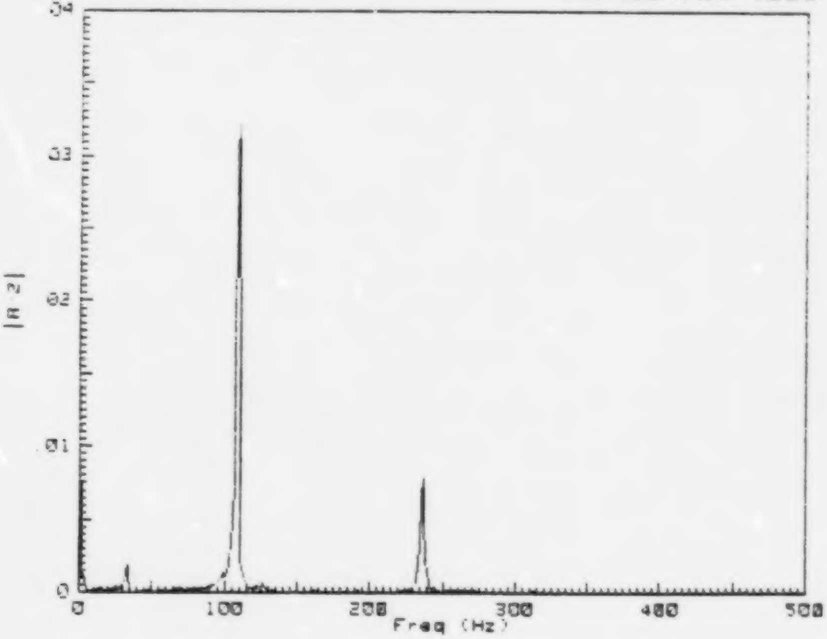
GEOTECHnical Resources Ltd. ANALYSIS DATE:27 Sep 1988

Blade Single-Axis Strain **Series PBT Test 17**



GEOTECHnical Resources Ltd. ANALYSIS DATE:27 Sep 1988

FFT of 1BS1 **Series PBT Test 17**



APPENDIX A.8

Minimum and Maximum Values of Data Plots

```
Test name: PBT01

Channel  Minimum      Mean         Maximum      Units  Channel Desciption
------------------------------------------------------------------------------
1BD1     -1.519E+01   -9.047E+00   2.650E-01    mm     Blade Displacement
1BD2     -1.128E+01   -6.694E+00   2.631E-01    mm     Blade Displacement
1BD3     -7.343E+00   -4.188E+00   2.622E-01    mm     Blade Displacement
1APR1     3.095E+00    6.547E+00   1.849E+01    MPa    Actuator Retract Pressure
1APE1     2.662E+00    4.327E+00   1.010E+01    MPa    Actuator Extend Pressure
1APR2     3.191E+00    6.084E+00   1.804E+01    MPa    Actuator Retract Pressure
1APE2     2.865E+00    4.294E+00   1.029E+01    MPa    Actuator Extend Pressure
1APR3     3.184E+00    6.242E+00   1.889E+01    MPa    Actuator Retract Pressure
1APE3     3.145E+00    4.563E+00   1.044E+01    MPa    Actuator Extend Pressure
1BP1     -1.003E-01    7.982E-01   3.481E+00    MPa    Blade Surface Pressure
1BP2     -1.007E-01   -3.584E-02   6.673E-02    MPa    Blade Surface Pressure
1BP3     -2.343E-01   -6.757E-02   7.645E+00    MPa    Blade Surface Pressure
1BP4      7.035E-01    1.861E+00   9.151E+00    MPa    Blade Surface Pressure
1BP5     -2.967E+01   -1.464E-01   5.492E+00    MPa    Blade Surface Pressure
1RAMP    -4.395E-02    3.421E+00   4.941E+00     V     Command
1BR1B    -6.641E+02   -3.843E+02   2.441E+00    uE     Blade Rosette Strain
1AD1      5.256E-01    1.867E+02   2.716E+02    mm     Actuator Displacement
1AD2      5.240E-01    1.832E+02   2.663E+02    mm     Actuator Displacement
1AD3      2.616E-01    1.826E+02   2.657E+02    mm     Actuator Displacement
1FSG1    -2.979E+02   -9.211E+01   1.489E+02    uE     Frame Girder Strain
1FSG2    -4.883E+00    7.180E+01   1.416E+02    uE     Frame Girder Strain
1FSG3    -1.221E+01    1.493E+02   2.783E+02    uE     Frame Girder Strain
1BS7     -2.100E+02   -9.798E+01   0.000E+00    uE     Blade Single-Axis Strain
1BS8     -2.881E+02   -1.671E+02   7.324E+00    uE     Blade Single-Axis Strain
1BS9     -1.416E+02    3.005E+02   7.178E+02    uE     Blade Single-Axis Strain
1BS1     -3.296E+02   -1.292E+02   0.000E+00    uE     Blade Single-Axis Strain
1BR2B    -1.465E+01    4.789E+02   8.350E+02    uE     Blade Rosette Strain
1BS3     -5.444E+02   -3.370E+02  -4.883E+00    uE     Blade Single-Axis Strain
1BS4     -3.247E+02   -1.629E+02  -7.324E+00    uE     Blade Single-Axis Strain
1BS5     -5.518E+02   -3.253E+02   0.000E+00    uE     Blade Single-Axis Strain
1BS6     -3.809E+02   -2.289E+02  -4.883E+00    uE     Blade Single-Axis Strain
1FSB2    -9.766E+00    8.228E+01   1.587E+02    uE     Frame Backstop Strain
```

```
Test name: PBT02

Channel  Minimum     Mean        Maximum     Units  Channel Desciption
------------------------------------------------------------------------------------
1BD1     -1.624E+01  -2.410E+00  -1.045E+00  mm     Blade Displacement
1BD2     -1.285E+01  -8.732E-01   2.631E-01  mm     Blade Displacement
1BD3     -7.081E+00  -1.946E+00  -1.311E+00  mm     Blade Displacement
1APR1     3.513E-01   1.623E+01   1.998E+01  MPa    Actuator Retract Pressure
1APE1    -1.686E-02   8.499E+00   1.068E+01  MPa    Actuator Extend Pressure
1APR2     5.089E+00   1.643E+01   1.987E+01  MPa    Actuator Retract Pressure
1APE2     3.351E+00   9.132E+00   1.128E+01  MPa    Actuator Extend Pressure
1APR3     1.340E+00   1.700E+01   2.088E+01  MPa    Actuator Retract Pressure
1APE3     7.024E-01   9.151E+00   1.148E+01  MPa    Actuator Extend Pressure
1BP1     -6.683E-02   1.285E-02   1.005E-01  MPa    Blade Surface Pressure
1BP2     -3.234E+01  -1.674E+00  -1.540E+00  MPa    Blade Surface Pressure
1BP3     -2.007E-01  -1.228E-01   1.006E+00  MPa    Blade Surface Pressure
1BP4      8.041E-01   8.714E-01   9.382E-01  MPa    Blade Surface Pressure
1BP5     -3.158E+01  -1.089E+00  -1.005E+00  MPa    Blade Surface Pressure
1RAMP    -3.418E-02   2.099E-01   1.602E+00   V     Command
1BR1B    -7.056E+02  -2.493E+01   4.883E+00  uE     Blade Rosette Strain
1AD1     -8.423E-04   1.331E+01   8.660E+01  mm     Actuator Displacement
1AD2      2.621E-01   1.384E+01   8.511E+01  mm     Actuator Displacement
1AD3      2.094E+00   1.545E+01   8.690E+01  mm     Actuator Displacement
1BR1A    -5.225E+02  -2.562E+01   0.000E+00  uE     Blade Rosette Strain
1FS62     0.000E+00   5.362E+00   1.294E+02  uE     Frame Girder Strain
1FSG3    -2.197E+01   9.399E+00   2.393E+02  uE     Frame Girder Strain
1BS7     -4.370E+02  -1.478E+01   2.441E+00  uE     Blade Single-Axis Strain
1BS8     -5.176E+02  -1.749E+01   7.324E+00  uE     Blade Single-Axis Strain
1BS9     -1.465E+01   1.152E+01   5.566E+02  uE     Blade Single-Axis Strain
1BS1     -3.833E+02  -1.892E+01   4.883E+00  uE     Blade Single-Axis Strain
1BR2B    -1.953E+01   2.695E+01   8.447E+02  uE     Blade Rosette Strain
1BS3     -7.080E+02  -3.560E+01   0.000E+00  uE     Blade Single-Axis Strain
1BS4     -6.592E+02  -3.189E+01   0.000E+00  uE     Blade Single-Axis Strain
1BS5     -6.055E+02  -2.527E+01   7.324E+00  uE     Blade Single-Axis Strain
1BS6     -6.592E+02  -2.665E+01   0.000E+00  uE     Blade Single-Axis Strain
1BR1C    -1.831E+02  -1.077E+01   0.000E+00  uE     Blade Rosette Strain
```

Test name: PBT03

Channel	Minimum	Mean	Maximum	Units	Channel Desciption
1BD1	-1.597E+01	-7.960E-01	5.273E-01	mm	Blade Displacement
1BD2	-1.417E+01	-1.143E+00	-4.280E-03	mm	Blade Displacement
1BD3	-5.503E+00	-1.470E-01	5.285E-01	mm	Blade Displacement
1APR1	5.655E+00	1.742E+01	2.061E+01	MPa	Actuator Retract Pressure
1APE1	2.579E+00	9.210E+00	1.095E+01	MPa	Actuator Extend Pressure
1APR2	5.038E+00	1.725E+01	2.051E+01	MPa	Actuator Retract Pressure
1APE2	3.418E+00	9.648E+00	1.156E+01	MPa	Actuator Extend Pressure
1APR3	4.927E+00	1.760E+01	2.128E+01	MPa	Actuator Retract Pressure
1APE3	3.563E+00	9.749E+00	1.193E+01	MPa	Actuator Extend Pressure
1BP1	-1.672E-01	1.305E-01	6.058E+00	MPa	Blade Surface Pressure
1BP2	-3.187E+01	-1.567E+00	3.548E+00	MPa	Blade Surface Pressure
1BP3	-2.007E-01	-1.063E-01	2.012E+00	MPa	Blade Surface Pressure
1BP4	8.041E-01	8.631E-01	1.039E+00	MPa	Blade Surface Pressure
1BP5	-3.135E+01	-1.089E+00	-9.712E-01	MPa	Blade Surface Pressure
1RAMP	-3.418E-02	1.972E-01	1.626E+00	V	Command
1BR1B	-7.739E+02	-4.020E+01	0.000E+00	uE	Blade Rosette Strain
1AD1	-1.052E+00	1.145E+01	8.633E+01	mm	Actuator Displacement
1AD2	-5.255E-01	1.185E+01	8.459E+01	mm	Actuator Displacement
1AD3	-2.643E-01	1.160E+01	8.481E+01	mm	Actuator Displacement
1BR1A	-5.615E+02	-3.744E+01	-1.465E+01	uE	Blade Rosette Strain
1FSG2	4.883E+00	1.161E+01	1.416E+02	uE	Frame Girder Strain
1FSG3	-1.953E+01	1.243E+01	2.539E+02	uE	Frame Girder Strain
1BS7	-4.565E+02	-1.979E+01	0.000E+00	uE	Blade Single-Axis Strain
1BS8	-5.542E+02	-2.672E+01	7.324E+00	uE	Blade Single-Axis Strain
1BS9	-1.221E+01	1.166E+01	5.908E+02	uE	Blade Single-Axis Strain
1BS1	-5.054E+02	-2.665E+01	4.883E+00	uE	Blade Single-Axis Strain
1BR2B	-2.197E+01	2.013E+01	8.984E+02	uE	Blade Rosette Strain
1BS3	-7.715E+02	-4.179E+01	-7.324E+00	uE	Blade Single-Axis Strain
1BS4	-6.860E+02	-3.532E+01	-7.324E+00	uE	Blade Single-Axis Strain
1BS5	-6.567E+02	-3.422E+01	0.000E+00	uE	Blade Single-Axis Strain
1BS6	-7.056E+02	-3.707E+01	-9.766E+00	uE	Blade Single-Axis Strain
1BR1C	-2.075E+02	-1.685E+01	-4.883E+00	uE	Blade Rosette Strain

```
Test name: PBT04

Channel  Minimum     Mean        Maximum     Units  Channel Desciption
--------------------------------------------------------------------------------
1BD1     -2.226E+01  -2.386E+00   1.051E+00  mm     Blade Displacement
1BD2     -1.626E+01  -2.259E+00  -4.280E-03  mm     Blade Displacement
1BD3     -8.650E+00  -8.933E-01   2.663E-01  mm     Blade Displacement
1APR1    -6.425E-05   3.618E+00   1.855E+01  MPa    Actuator Retract Pressure
1APE1    -1.686E-02   2.114E+00   1.073E+01  MPa    Actuator Extend Pressure
1APR2    -1.712E-02   3.696E+00   1.851E+01  MPa    Actuator Retract Pressure
1APE2    -6.702E-02   2.220E+00   1.061E+01  MPa    Actuator Extend Pressure
1APR3    -3.375E-02   3.584E+00   1.726E+01  MPa    Actuator Retract Pressure
1APE3    -6.725E-02   2.355E+00   1.139E+01  MPa    Actuator Extend Pressure
1BP1     -1.006E-01   1.461E-02   1.874E+00  MPa    Blade Surface Pressure
1BP2     -3.013E+01  -7.539E-01  -5.021E-01  MPa    Blade Surface Pressure
1BP3     -6.752E-02   5.423E-02   3.286E+00  MPa    Blade Surface Pressure
1BP4     -1.676E-01   7.213E-02   8.414E+00  MPa    Blade Surface Pressure
1BP5     -3.058E+01  -1.048E+00   4.119E+00  MPa    Blade Surface Pressure
1RAMP    -3.906E-02   1.373E+00   4.849E+00    V    Command
1BR1B    -1.199E+03  -1.255E+02  -1.465E+01  uE     Blade Rosetta Strain
1AD1     -7.888E-01   1.730E+02   2.645E+02  mm     Actuator Displacement
1AD2      7.839E-01   1.746E+02   2.616E+02  mm     Actuator Displacement
1AD3      1.830E+00   1.715E+02   2.620E+02  mm     Actuator Displacement
1BR1A    -5.469E+02  -7.484E+01  -1.709E+01  uE     Blade Rosette Strain
1FSG2     2.441E+00   2.566E+01   2.344E+02  uE     Frame Girder Strain
1FSG3    -7.324E+00   4.800E+01   5.078E+02  uE     Frame Girder Strain
1BS7     -2.783E+02  -2.298E+01   1.221E+01  uE     Blade Single-Axis Strain
1BS8     -4.639E+02  -4.960E+01   9.766E+00  uE     Blade Single-Axis Strain
1BS9     -2.197E+01   4.235E+01   6.006E+02  uE     Blade Single-Axis Strain
1BS1     -2.612E+02  -4.223E+00   3.662E+01  uE     Blade Single-Axis Strain
1BR2B    -3.418E+01   1.211E+02   1.304E+03  uE     Blade Rosette Strain
1BS3     -1.062E+03  -1.045E+02   2.441E+00  uE     Blade Single-Axis Strain
1BS4     -4.395E+02  -4.966E+01   0.000E+00  uE     Blade Single-Axis Strain
1BS5     -9.912E+02  -1.045E+02  -4.883E+00  uE     Blade Single-Axis Strain
1BS6     -6.396E+02  -7.296E+01  -7.324E+00  uE     Blade Single-Axis Strain
1BR1C    -6.055E+02  -6.144E+01  -4.883E+00  uE     Blade Rosette Strain
```

```
Test name: PBT05

Channel  Minimum     Mean        Maximum     Units  Channel Desciption
--------------------------------------------------------------------------------
1BD1     -9.950E+00  -9.724E-01   1.575E+00  mm     Blade Displacement
1BD2     -9.445E+00  -8.396E-01   7.825E-01  mm     Blade Displacement
1BD3     -4.192E+00  -2.726E-01   5.285E-01  mm     Blade Displacement
1APR1     4.367E+00   1.229E+01   1.877E+01  MPa    Actuator Retract Pressure
1APE1     2.344E+00   6.311E+00   9.795E+00  MPa    Actuator Extend Pressure
1APR2     2.200E+00   1.228E+01   2.158E+01  MPa    Actuator Retract Pressure
1APE2     5.362E-06   6.777E+00   1.051E+01  MPa    Actuator Extend Pressure
1APR3     4.323E+00   1.243E+01   1.781E+01  MPa    Actuator Retract Pressure
1APE3     2.844E+00   6.838E+00   9.302E+00  MPa    Actuator Extend Pressure
1BP1     -6.716E-02   6.076E-02   2.242E+00  MPa    Blade Surface Pressure
1BR2A     8.545E+01   1.032E+02   3.735E+02  uE     Blade Rosette Strain
1BP3     -6.752E-02   6.941E-03   3.013E-01  MPa    Blade Surface Pressure
1BP4     -6.704E-02   6.277E-02   2.280E+00  MPa    Blade Surface Pressure
1BR2C    -2.244E+03  -7.694E+01   4.883E+01  MPa    Blade Rosette Strain
1RAMP    -2.930E-02   6.836E-01   3.384E+00   V     Command
1BR1B    -4.712E+02  -4.000E+01   0.000E+00  uE     Blade Rosette Strain
1AD1     -1.842E+00   4.611E+01   1.803E+02  mm     Actuator Displacement
1AD2     -3.144E+00   4.541E+01   1.760E+02  mm     Actuator Displacement
1AD3     -5.238E+00   4.153E+01   1.733E+02  mm     Actuator Displacement
1BR1A    -3.516E+02  -3.853E+01  -1.465E+01  uE     Blade Rosette Strain
1FSG2    -1.709E+01   4.736E+00   9.033E+01  uE     Frame Girder Strain
1FSG3    -9.766E+00   1.336E+01   1.733E+02  uE     Frame Girder Strain
1BS7     -2.075E+02  -1.350E+01   4.883E+00  uE     Blade Single-Axis Strain
1BS8     -3.076E+02  -2.650E+01   2.441E+00  uE     Blade Single-Axis Strain
1BS9     -3.174E+01  -4.527E+00   3.052E+02  uE     Blade Single-Axis Strain
1BS1     -5.371E+01   1.439E+01   1.074E+02  uE     Blade Single-Axis Strain
1BR2B    -2.441E+01   4.591E+01   5.737E+02  uE     Blade Rosette Strain
1BS3     -3.882E+02  -3.495E+01  -7.324E+00  uE     Blade Single-Axis Strain
1BS4     -2.783E+02  -2.744E+01  -4.883E+00  uE     Blade Single-Axis Strain
1BS5     -3.882E+02  -3.887E+01  -9.766E+00  uE     Blade Single-Axis Strain
1BS6     -3.809E+02  -3.411E+01  -7.324E+00  uE     Blade Single-Axis Strain
1BR1C    -1.465E+02  -2.582E+01  -1.465E+01  uE     Blade Rosette Strain
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Test name: PBT06

Channel  Minimum     Mean        Maximum     Units  Channel Desciption
----------------------------------------------------------------------------------
1BD1     -1.336E+01  -3.758E+00   1.051E+00  mm     Blade Displacement
1BD2     -1.102E+01  -3.178E+00   5.202E-01  mm     Blade Displacement
1BD3     -5.241E+00  -1.511E+00   2.663E-01  mm     Blade Displacement
1APR1    -3.353E-02   5.762E+00   2.735E+01  MPa    Actuator Retract Pressure
1APE1    -1.686E-02   2.926E+00   1.139E+01  MPa    Actuator Extend Pressure
1APR2    -1.712E-02   5.623E+00   2.741E+01  MPa    Actuator Retract Pressure
1APE2    -6.702E-02   3.575E+00   3.382E+01  MPa    Actuator Extend Pressure
1APR3    -3.375E-02   5.418E+00   2.118E+01  MPa    Actuator Retract Pressure
1APE3    -5.052E-02   3.512E+00   1.133E+01  MPa    Actuator Extend Pressure
1BF1     -1.006E-01   8.407E-02   2.108E+00  MPa    Blade Surface Pressure
1BP2      1.138E+00   1.411E+00   3.615E+00  MPa    Blade Surface Pressure
1BP3     -1.011E-01   1.063E-02   2.347E+00  MPa    Blade Surface Pressure
1BP4     -1.341E-01   3.528E-01   2.011E+00  MPa    Blade Surface Pressure
1BP5     -3.272E+01  -7.816E-01   5.358E-01  MPa    Blade Surface Pressure
1RAMP    -3.418E-02   2.436E+00   4.849E+00   V     Command
1BR1B    -6.323E+02  -1.794E+02  -1.709E+01  uE     Blade Rosette Strain
1AD1     -2.105E+00   1.831E+02   2.627E+02  mm     Actuator Displacement
1AD2     -2.882E+00   1.803E+02   2.577E+02  mm     Actuator Displacement
1AD3     -5.761E+00   1.765E+02   2.547E+02  mm     Actuator Displacement
1BR1A    -4.004E+02  -1.204E+02  -2.197E+01  uE     Blade Rosette Strain
1FSG2    -7.324E+00   3.395E+01   1.270E+02  uE     Frame Girder Strain
1FSG3     0.000E+00   7.016E+01   2.588E+02  uE     Frame Girder Strain
1BS7     -2.075E+02  -5.003E+01   9.766E+00  uE     Blade Single-Axis Strain
1BS8     -3.369E+02  -9.199E+01   2.441E+00  uE     Blade Single-Axis Strain
1BS9     -3.662E+01   6.650E+01   3.491E+02  uE     Blade Single-Axis Strain
1BS1     -1.074E+02  -1.689E+01   4.883E+01  uE     Blade Single-Axis Strain
1BR2B    -4.150E+01   1.581E+02   6.958E+02  uE     Blade Rosette Strain
1BS3     -5.029E+02  -1.361E+02   4.883E+00  uE     Blade Single-Axis Strain
1BS4     -2.930E+02  -7.807E+01   2.441E+00  uE     Blade Single-Axis Strain
1BS5     -5.078E+02  -1.445E+02  -9.766E+00  uE     Blade Single-Axis Strain
1BS6     -4.224E+02  -1.170E+02  -9.766E+00  uE     Blade Single-Axis Strain
1BR1C    -2.441E+02  -8.180E+01  -1.953E+01  uE     Blade Rosette Strain
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Test name: PBT07

Channel  Minimum     Mean        Maximum     Units  Channel Desciption
--------------------------------------------------------------------------------
1BD1     -1.257E+01  -3.611E+00  7.893E-01   mm     Blade Displacement
1BD2     -3.171E+02  -1.467E+02  2.198E+02   mm     Blade Displacement
1BD3     -4.454E+00  -1.189E+00  2.663E-01   mm     Blade Displacement
1APR1    -3.353E-02   5.483E+00  2.628E+01   MPa    Actuator Retract Pressure
1APE1    -1.686E-02   2.631E+00  9.896E+00   MPa    Actuator Extend Pressure
1APR2    -3.392E-02   4.742E+00  2.638E+01   MPa    Actuator Retract Pressure
1APE2    -6.702E-02   2.941E+00  3.382E+01   MPa    Actuator Extend Pressure
1APR3    -6.726E-02   4.397E+00  1.924E+01   MPa    Actuator Retract Pressure
1APE3    -5.052E-02   2.927E+00  1.057E+01   MPa    Actuator Extend Pressure
1BP1     -6.716E-02   1.355E-01  1.841E+00   MPa    Blade Surface Pressure
1BP2     -2.338E-01   6.134E-02  1.139E+00   MPa    Blade Surface Pressure
1BP3     -3.399E-02   2.431E-01  4.157E+00   MPa    Blade Surface Pressure
1BP4     -1.341E-01   8.877E-02  2.112E+00   MPa    Blade Surface Pressure
1BP5     -2.599E+01  -1.027E+00  1.674E-01   MPa    Blade Surface Pressure
1RAMP    -3.418E-02   2.270E+00  4.849E+00    V     Command
1BR1B    -4.761E+02  -1.404E+02  9.766E+00   uE     Blade Rosette Strain
1AD1     -1.052E+00   1.909E+02  2.651E+02   mm     Actuator Displacement
1AD2     -1.311E+00   1.879E+02  2.598E+02   mm     Actuator Displacement
1AD3     -6.023E+00   1.824E+02  2.547E+02   mm     Actuator Displacement
1BR1A    -3.955E+02  -1.267E+02  0.000E+00   uE     Blade Rosette Strain
1FSG2     2.441E+00   2.896E+01  9.277E+01   uE     Frame Girder Strain
1FSG3     0.000E+00   5.193E+01  1.563E+02   uE     Frame Girder Strain
1BS7     -4.004E+02  -1.209E+02  1.465E+01   uE     Blade Single-Axis Strain
1BS8     -4.004E+02  -9.955E+01  9.033E+01   uE     Blade Single-Axis Strain
1BS9     -1.465E+01   1.300E+02  4.346E+02   uE     Blade Single-Axis Strain
1BS1     -3.662E+02  -8.603E+01  3.418E+01   uE     Blade Single-Axis Strain
1BR2B    -1.465E+01   1.923E+02  6.079E+02   uE     Blade Rosette Strain
1BS3     -5.225E+02  -1.527E+02  4.883E+00   uE     Blade Single-Axis Strain
1BS4     -6.030E+02  -1.882E+02  2.441E+00   uE     Blade Single-Axis Strain
1BS5     -4.224E+02  -1.262E+02  2.441E+00   uE     Blade Single-Axis Strain
1BS6     -5.078E+02  -1.560E+02  4.883E+00   uE     Blade Single-Axis Strain
1BR1C    -9.766E+01  -2.913E+01  0.000E+00   uE     Blade Rosette Strain
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Test name: PBT08

Channel  Minimum     Mean        Maximum     Units  Channel Desciption
-------------------------------------------------------------------------------
1BD1     -1.597E+01  -2.560E+00   5.273E-01  mm     Blade Displacement
1BD2     -3.095E+01  -3.394E+00   2.096E+00  mm     Blade Displacement
1BD3     -7.339E+00  -2.397E+00  -1.307E+00  mm     Blade Displacement
1APR1    -5.026E-02   4.867E+00   1.730E+01  MPa    Actuator Retract Pressure
1APE1    -1.686E-02   2.751E+00   9.795E+00  MPa    Actuator Extend Pressure
1APR2    -6.751E-02   4.668E+00   1.785E+01  MPa    Actuator Retract Pressure
1APE2    -5.027E-02   2.962E+00   9.920E+00  MPa    Actuator Extend Pressure
1APR3    -5.051E-02   4.872E+00   2.492E+01  MPa    Actuator Retract Pressure
1APE3    -6.725E-02   2.509E+00   1.002E+01  MPa    Actuator Extend Pressure
1BP1     -3.369E-02   7.364E-02   7.162E+00  MPa    Blade Surface Pressure
1BP2     -2.003E-01   5.372E-02   1.239E+00  MPa    Blade Surface Pressure
1BP3     -6.752E-02   1.404E-01   6.102E+00  MPa    Blade Surface Pressure
1BP4     -6.704E-02   5.436E-02   2.347E-01  MPa    Blade Surface Pressure
1BP5     -1.343E-01   2.635E-02   3.346E-01  MPa    Blade Surface Pressure
1RAMP    -2.930E-02   2.199E+00   4.849E+00    V    Command
1BR1B    -7.397E+02  -6.654E+01   1.465E+01  uE     Blade Rosette Strain
1AD1      1.318E+00   1.822E+02   2.669E+02  mm     Actuator Displacement
1AD2      3.666E+00   1.805E+02   2.642E+02  mm     Actuator Displacement
1AD3     -2.876E+00   1.735E+02   2.568E+02  mm     Actuator Displacement
1BR1A    -6.152E+02  -7.013E+01   2.441E+00  uE     Blade Rosette Strain
1BR2A    -9.766E+00   3.446E+01   1.929E+02  uE     Blade Rosette Strain
1FSG3    -9.766E+00   2.646E+01   2.295E+02  uE     Frame Girder Strain
1BS7     -6.689E+02  -5.060E+01   1.709E+01  uE     Blade Single-Axis Strain
1BS8     -6.567E+02  -6.310E+01   1.221E+01  uE     Blade Single-Axis Strain
1BS9     -1.953E+01   5.773E+01   6.738E+02  uE     Blade Single-Axis Strain
1BS1     -3.638E+02  -6.301E-01   3.662E+01  uE     Blade Single-Axis Strain
1BR2B    -1.221E+01   1.041E+02   9.009E+02  uE     Blade Rosette Strain
1BS3     -7.178E+02  -6.199E+01   4.883E+00  uE     Blade Single-Axis Strain
1BS4     -9.399E+02  -8.321E+01   2.441E+00  uE     Blade Single-Axis Strain
1BS2     -8.667E+02  -2.444E+01   3.418E+01  uE     Blade Single-Axis Strain
1BR2C    -2.441E+01   7.528E+01   6.274E+02  uE     Blade Rosette Strain
1BR1C    -1.416E+02  -1.265E+01   2.441E+00  uE     Blade Rosette Strain
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Test name: PBT09

Channel  Minimum     Mean        Maximum     Units  Channel Desciption
-----------------------------------------------------------------------------------
1BD1     -3.012E+01  -8.008E+00   7.338E+00  mm     Blade Displacement
1BD2     -9.389E+01  -7.291E-01   1.130E+02  mm     Blade Displacement
1BD3     -1.311E+01  -4.460E+00   1.053E+00  mm     Blade Displacement
1APR1    -5.026E-02   6.458E+00   2.687E+01  MPa    Actuator Retract Pressure
1APE1    -1.686E-02   3.410E+00   8.188E+00  MPa    Actuator Extend Pressure
1APR2    -6.751E-02   5.802E+00   1.538E+01  MPa    Actuator Retract Pressure
1APE2    -6.702E-02   3.908E+00   8.831E+00  MPa    Actuator Extend Pressure
1APR3    -8.402E-02   5.578E+00   1.542E+01  MPa    Actuator Retract Pressure
1APE3    -3.266E-04   3.816E+00   8.884E+00  MPa    Actuator Extend Pressure
1BP1     -1.006E-01   1.090E-01   6.392E+00  MPa    Blade Surface Pressure
1BP2     -2.338E-01   4.872E-02   3.716E+00  MPa    Blade Surface Pressure
1BP3     -1.011E-01   1.037E-02   4.157E+00  MPa    Blade Surface Pressure
1BP4     -1.006E-01   1.399E-01   7.543E+00  MPa    Blade Surface Pressure
1BP5     -2.347E-01   8.125E-03   6.597E+00  MPa    Blade Surface Pressure
1RAMP    -2.441E-02   3.319E+00   4.854E+00   V     Command
1BR1B    -1.387E+03  -3.069E+02   2.930E+01  uE     Blade Rosette Strain
1AD1      1.845E+00   2.050E+02   2.680E+02  mm     Actuator Displacement
1AD2      2.618E+00   2.022E+02   2.640E+02  mm     Actuator Displacement
1AD3      2.883E+00   2.018E+02   2.636E+02  mm     Actuator Displacement
1BR1A    -1.267E+03  -2.354E+02   0.000E+00  uE     Blade Rosette Strain
1BR2A    -9.766E+00   9.633E+01   4.248E+02  uE     Blade Rosette Strain
1FSG3    -9.302E+02   9.348E+01   4.639E+02  uE     Frame Girder Strain
1BS7     -1.682E+03  -2.168E+02   1.221E+01  uE     Blade Single-Axis Strain
1BS8     -1.528E+03  -2.351E+02   2.930E+01  uE     Blade Single-Axis Strain
1BS9     -3.174E+01   2.432E+02   1.509E+03  uE     Blade Single-Axis Strain
1BS1     -8.179E+02  -2.199E+02   7.324E+00  uE     Blade Single-Axis Strain
1BR2B    -1.221E+01   3.979E+02   1.702E+03  uE     Blade Rosette Strain
1BS3     -1.140E+03  -3.400E+02   2.441E+00  uE     Blade Single-Axis Strain
1BS4     -1.863E+03  -3.153E+02  -4.883E+00  uE     Blade Single-Axis Strain
1BS2     -8.105E+02  -1.527E+02   0.000E+00  uE     Blade Single-Axis Strain
1BR2C    -2.344E+02   2.609E+02   1.377E+03  uE     Blade Rosette Strain
1BR1C    -3.955E+02  -8.924E+01  -4.883E+00  uE     Blade Rosette Strain
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Test name: PBT10  .

Channel  Minimum     Mean        Maximum     Units  Channel Desciption
--------------------------------------------------------------------------------
1BD1     -1.100E+01   4.450E-02   1.572E+00  mm     Blade Displacement
1BD2     -3.041E+01  -2.360E+00   1.066E+00  mm     Blade Displacement
1BD3     -3.930E+00   4.175E-01   1.316E+00  mm     Blade Displacement
1APR1    -8.372E-02   5.540E+00   2.806E+01  MPa    Actuator Retract Pressure
1APE1    -1.686E-02   2.556E+00   9.762E+00  MPa    Actuator Extend Pressure
1APR2    -1.011E-01   5.535E+00   2.813E+01  MPa    Actuator Retract Pressure
1APE2    -6.702E-02   3.073E+00   1.141E+01  MPa    Actuator Extend Pressure
1APR3    -8.402E-02   5.429E+00   2.148E+01  MPa    Actuator Retract Pressure
1APE3    -8.398E-02   2.791E+00   1.057E+01  MPa    Actuator Extend Pressure
1BP1     -1.341E-01  -3.823E-02   3.324E-02  MPa    Blade Surface Pressure
1BP2     -3.294E-02   6.797E-02   4.023E-01  MPa    Blade Surface Pressure
1BP3     -6.752E-02   2.308E-03   6.660E-02  MPa    Blade Surface Pressure
1BP4      1.073E-05   8.287E-02   1.676E-01  MPa    Blade Surface Pressure
1BP5     -6.730E-02   4.095E-02   1.671E-01  MPa    Blade Surface Pressure
1RAMP    -2.441E-02   8.635E-01   3.867E+00    V    Command
1BR1B    -5.640E+02  -4.808E+01  -1.953E+01  uE     Blade Rosette Strain
1AD1      2.371E+00   7.180E+01   2.103E+02  mm     Actuator Displacement
1AD2      1.833E+00   7.196E+01   2.058E+02  mm     Actuator Displacement
1AD3     -1.306E+00   6.843E+01   2.026E+02  mm     Actuator Displacement
1BR1A    -6.445E+02  -4.770E+01  -1.709E+01  uE     Blade Rosette Strain
1BR2A    -1.709E+01  -9.670E+00   2.197E+01  uE     Blade Rosette Strain
1FSG3    -1.953E+01   6.191E+00   1.611E+02  uE     Frame Girder Strain
1BS7     -9.961E+02  -6.120E+01  -1.709E+01  uE     Blade Single-Axis Strain
1BS8     -7.813E+02  -5.685E+01   2.441E+00  uE     Blade Single-Axis Strain
1BS9     -9.766E+00   2.413E+01   7.324E+02  uE     Blade Single-Axis Strain
1BS1     -5.615E+01  -1.881E+01  -7.324E+00  uE     Blade Single-Axis Strain
1BR2B     0.000E+00   3.517E+01   7.178E+02  uE     Blade Rosette Strain
1BS3     -3.857E+02  -3.716E+01  -1.465E+01  uE     Blade Single-Axis Strain
1BS4     -1.038E+03  -6.702E+01  -2.197E+01  uE     Blade Single-Axis Strain
1BS2     -8.569E+02  -6.296E+01  -1.709E+01  uE     Blade Single-Axis Strain
1BR2C     4.998E+03   4.998E+03   4.998E+03  uE     Blade Rosette Strain
1BR1C    -2.930E+01  -1.957E+01   1.221E+01  uE     Blade Rosette Strain
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Test name: PBT11

Channel	Minimum	Mean	Maximum	Units	Channel Desciption
1BD1	-2.855E+01	-6.240E+00	1.048E+00	mm	Blade Displacement
1BD2	-5.742E+01	-1.455E+01	-1.295E+00	mm	Blade Displacement
1BD3	-9.961E+00	-1.903E+00	1.053E+00	mm	Blade Displacement
1APR1	-5.026E-02	6.517E+00	2.128E+01	MPa	Actuator Retract Pressure
1APE1	-1.686E-02	3.758E+00	1.149E+01	MPa	Actuator Extend Pressure
1APR2	-5.071E-02	6.081E+00	2.353E+01	MPa	Actuator Retract Pressure
1APE2	-8.378E-02	4.271E+00	1.952E+01	MPa	Actuator Extend Pressure
1APR3	-8.402E-02	6.151E+00	1.967E+01	MPa	Actuator Retract Pressure
1APE3	-1.174E-01	4.005E+00	1.191E+01	MPa	Actuator Extend Pressure
1BP1	-1.006E-01	-3.249E-02	2.510E+00	MPa	Blade Surface Pressure
1BP2	-9.989E-02	1.632E-01	2.310E+00	MPa	Blade Surface Pressure
1BP3	-6.752E-02	1.129E+00	6.203E+00	MPa	Blade Surface Pressure
1BP4	-6.704E-02	6.445E-02	3.352E-01	MPa	Blade Surface Pressure
1BP5	-1.343E-01	3.592E-02	7.029E-01	MPa	Blade Surface Pressure
1RAMP	-2.930E-02	2.626E+00	4.854E+00	V	Command
1BR1B	-1.514E+03	-3.369E+02	-1.709E+01	uE	Blade Rosette Strain
1AD1	2.371E+00	1.901E+02	2.677E+02	mm	Actuator Displacement
1AD2	1.833E+00	1.863E+02	2.624E+02	mm	Actuator Displacement
1AD3	2.359E+00	1.862E+02	2.628E+02	mm	Actuator Displacement
1BR1A	-1.304E+03	-3.141E+02	-2.197E+01	uE	Blade Rosette Strain
1BR2A	-1.758E+02	4.656E+01	4.175E+02	uE	Blade Rosette Strain
1FSG3	-3.638E+02	9.636E+01	4.736E+02	uE	Frame Girder Strain
1BS7	-1.765E+03	-3.848E+02	-2.197E+01	uE	Blade Single-Axis Strain
1BS8	-1.572E+03	-3.489E+02	3.174E+01	uE	Blade Single-Axis Strain
1BS9	-2.930E+01	3.099E+02	1.523E+03	uE	Blade Single-Axis Strain
1BS1	-6.079E+02	-1.071E+02	1.953E+01	uE	Blade Single-Axis Strain
1BR2B	-2.344E+02	3.942E+02	1.812E+03	uE	Blade Rosette Strain
1BS3	-1.326E+03	-2.994E+02	-1.953E+01	uE	Blade Single-Axis Strain
1BS4	-2.195E+03	-4.888E+02	-1.953E+01	uE	Blade Single-Axis Strain
1BS2	-1.560E+03	-2.650E+02	1.221E+01	uE	Blade Single-Axis Strain
1BR2C	4.998E+03	4.998E+03	4.998E+03	uE	Blade Rosette Strain
1BR1C	-2.588E+02	-5.524E+01	-1.709E+01	uE	Blade Rosette Strain

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Test name: PBT12

Channel  Minimum     Mean        Maximum     Units  Channel Desciption
-------------------------------------------------------------------------------
1BD1     -3.065E+01  -8.287E+00   5.241E-01  mm     Blade Displacement
1BD2     -5.348E+01  -1.580E+01  -1.295E+00  mm     Blade Displacement
1BD3     -1.049E+01  -2.717E+00   7.910E-01  mm     Blade Displacement
1APR1    -6.425E-05   5.073E+00   2.050E+01  MPa    Actuator Retract Pressure
1APE1    -1.686E-02   3.678E+00   1.087E+01  MPa    Actuator Extend Pressure
1APR2    -5.071E-02   5.370E+00   3.154E+01  MPa    Actuator Retract Pressure
1APE2    -6.702E-02   3.786E+00   2.306E+01  MPa    Actuator Extend Pressure
1APR3    -3.375E-02   5.166E+00   2.085E+01  MPa    Actuator Retract Pressure
1APE3    -6.725E-02   3.492E+00   1.235E+01  MPa    Actuator Extend Pressure
1BP1     -1.006E-01   3.925E-01   6.694E+00  MPa    Blade Surface Pressure
1BP2     -1.668E-01   1.269E-01   2.310E+00  MPa    Blade Surface Pressure
1BP3     -1.011E-01   2.629E+00   1.331E+01  MPa    Blade Surface Pressure
1BP4     -6.704E-02   1.442E-01   2.481E+00  MPa    Blade Surface Pressure
1BP5     -1.343E-01   9.119E-02   1.574E+00  MPa    Blade Surface Pressure
1RAMP    -2.930E-02   1.856E+00   4.854E+00    V    Command
1BR1B    -1.641E+03  -4.264E+02  -1.465E+01  uE     Blade Rosette Strain
1AD1      2.897E+00   1.739E+02   2.687E+02  mm     Actuator Displacement
1AD2      1.309E+00   1.688E+02   2.619E+02  mm     Actuator Displacement
1AD3      6.024E+00   1.740E+02   2.662E+02  mm     Actuator Displacement
1BR1A    -1.345E+03  -3.679E+02  -1.953E+01  uE     Blade Rosette Strain
1BR2A    -7.324E+00   8.945E+01   3.638E+02  uE     Blade Rosette Strain
1FSG3    -1.465E+01   1.256E+02   5.078E+02  uE     Frame Girder Strain
1BS7     -1.636E+03  -4.101E+02  -2.686E+01  uE     Blade Single-Axis Strain
1BS8     -1.567E+03  -4.051E+02   0.000E+00  uE     Blade Single-Axis Strain
1BS9     -1.465E+01   3.778E+02   1.563E+03  uE     Blade Single-Axis Strain
1BS1     -7.495E+02  -1.485E+02   2.441E+01  uE     Blade Single-Axis Strain
1BR2B     1.465E+01   5.266E+02   1.970E+03  uE     Blade Rosette Strain
1BS3     -1.465E+03  -3.885E+02  -2.441E+01  uE     Blade Single-Axis Strain
1BS4     -2.080E+03  -5.296E+02  -3.174E+01  uE     Blade Single-Axis Strain
1BS2     -8.496E+02  -1.588E+02   2.686E+01  uE     Blade Single-Axis Strain
1BR2C    -1.955E+01   3.714E+02   1.453E+03  uE     Blade Rosette Strain
1BR1C    -3.320E+02  -8.587E+01  -1.709E+01  uE     Blade Rosette Strain
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Test name: PBT13

Channel	Minimum	Mean	Maximum	Units	Channel Desciption
1BD1	-5.236E-01	-2.849E-01	2.515E-04	mm	Blade Displacement
1BD2	-3.393E+00	-2.925E+00	-2.344E+00	mm	Blade Displacement
1BD3	4.280E-03	3.049E-01	5.288E-01	mm	Blade Displacement
1APR1	-5.026E-02	2.310E+01	3.068E+01	MPa	Actuator Retract Pressure
1APE1	-1.686E-02	1.280E+01	1.646E+01	MPa	Actuator Extend Pressure
1APR2	-5.071E-02	1.792E+01	2.287E+01	MPa	Actuator Retract Pressure
1APE2	-8.378E-02	1.046E+01	1.317E+01	MPa	Actuator Extend Pressure
1APR3	-6.726E-02	1.802E+01	2.226E+01	MPa	Actuator Retract Pressure
1APE3	-8.398E-02	1.049E+01	1.287E+01	MPa	Actuator Extend Pressure
1BP1	-1.006E-01	-3.186E-02	-2.249E-04	MPa	Blade Surface Pressure
1BP2	5.356E-04	5.963E-02	1.344E-01	MPa	Blade Surface Pressure
1BP3	-1.011E-01	-6.468E-02	-4.614E-04	MPa	Blade Surface Pressure
1BP4	3.353E-02	7.409E-02	1.341E-01	MPa	Blade Surface Pressure
1BP5	-3.215E-04	5.471E-02	1.001E-01	MPa	Blade Surface Pressure
1RAMP	-3.906E-02	2.407E+00	4.951E+00	V	Command
1BR1B	-3.906E+01	-3.639E+01	-3.174E+01	uE	Blade Rosette Strain
1AD1	2.106E-03	1.371E+02	2.708E+02	mm	Actuator Displacement
1AD2	-5.028E-04	1.353E+02	2.666E+02	mm	Actuator Displacement
1AD3	3.930E+00	1.392E+02	2.701E+02	mm	Actuator Displacement
1BR1A	-3.418E+01	-3.243E+01	-2.930E+01	uE	Blade Rosette Strain
1BR2A	-4.883E+00	-6.270E-02	0.000E+00	uE	Blade Rosette Strain
1FSG3	-9.766E+00	4.147E+00	1.709E+01	uE	Frame Girder Strain
1BS7	-4.395E+01	-4.141E+01	-3.906E+01	uE	Blade Single-Axis Strain
1BS8	-6.592E+01	-3.947E+01	-1.221E+01	uE	Blade Single-Axis Strain
1BS9	-1.953E+01	-1.476E+01	-9.766E+00	uE	Blade Single-Axis Strain
1BS1	-1.465E+01	-1.043E+01	-7.324E+00	uE	Blade Single-Axis Strain
1BR2B	2.441E+01	2.787E+01	3.418E+01	uE	Blade Rosette Strain
1BS3	-4.150E+01	-3.755E+01	-3.418E+01	uE	Blade Single-Axis Strain
1BS4	-4.639E+01	-4.197E+01	-3.906E+01	uE	Blade Single-Axis Strain
1BS2	-1.465E+01	-9.720E+00	-4.883E+00	uE	Blade Single-Axis Strain
1BR2C	-2.931E+01	-2.549E+01	-2.199E+01	uE	Blade Rosette Strain
1BR1C	-3.906E+01	-3.521E+01	-3.174E+01	uE	Blade Rosette Strain

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Test name: PBT14

Channel  Minimum      Mean         Maximum      Units  Channel Desciption
-------------------------------------------------------------------------------
1BD1     -4.034E+01   -3.887E+00    2.515E-04   mm     Blade Displacement
1BD2     -5.925E+01   -8.122E+00   -2.606E+00   mm     Blade Displacement
1BD3     -1.494E+01   -1.144E+00    5.288E-01   mm     Blade Displacement
1APR1    -5.026E-02    1.140E+01    2.603E+01   MPa    Actuator Retract Pressure
1APE1    -1.686E-02    6.797E+00    1.460E+01   MPa    Actuator Extend Pressure
1APR2    -6.751E-02    9.568E+00    2.178E+01   MPa    Actuator Retract Pressure
1APE2    -2.011E-01    5.962E+00    1.267E+01   MPa    Actuator Extend Pressure
1APR3    -1.175E-01    1.163E+01    2.619E+01   MPa    Actuator Retract Pressure
1APE3    -1.174E-01    6.865E+00    1.482E+01   MPa    Actuator Extend Pressure
1BP1     -1.006E-01   -2.861E-02   -2.249E-04   MPa    Blade Surface Pressure
1BP2      5.356E-04    5.758E-02    1.344E-01   MPa    Blade Surface Pressure
1BP3     -1.346E-01    4.795E-01    1.231E+01   MPa    Blade Surface Pressure
1BP4      3.353E-02    6.931E-02    1.341E-01   MPa    Blade Surface Pressure
1BP5     -3.215E-04    5.479E-02    1.001E-01   MPa    Blade Surface Pressure
1RAMP    -3.906E-02    1.151E+00    4.233E+00    V     Command
1BR1B    -2.380E+03   -2.268E+02   -2.930E+01   uE     Blade Rosette Strain
1AD1      2.634E+00    1.249E+02    2.351E+02   mm     Actuator Displacement
1AD2      1.833E+00    1.199E+02    2.299E+02   mm     Actuator Displacement
1AD3      3.668E+00    1.239E+02    2.314E+02   mm     Actuator Displacement
1BR1A    -1.790E+03   -1.773E+02   -2.686E+01   uE     Blade Rosette Strain
1BR2A    -4.883E+00    5.315E+01    6.274E+02   uE     Blade Rosette Strain
1FSG3    -9.766E+00    7.058E+01    8.130E+02   uE     Frame Girder Strain
1BS7     -1.611E+03   -1.682E+02   -3.662E+01   uE     Blade Single-Axis Strain
1BS8     -2.100E+03   -2.126E+02   -1.221E+01   uE     Blade Single-Axis Strain
1BS9     -1.709E+01    1.410E+02    1.960E+03   uE     Blade Single-Axis Strain
1BS1     -4.858E+02   -3.468E+01    1.953E+01   uE     Blade Single-Axis Strain
1BR2B     2.197E+01    2.545E+02    2.817E+03   uE     Blade Rosette Strain
1BS3     -1.685E+03   -1.671E+02   -3.174E+01   uE     Blade Single-Axis Strain
1BS4     -2.107E+03   -2.130E+02   -3.662E+01   uE     Blade Single-Axis Strain
1BS2     -7.080E+02   -4.729E+01    2.686E+01   uE     Blade Single-Axis Strain
1BR2C    -2.931E+01    1.499E+02    2.026E+03   uE     Blade Rosette Strain
1BR1C    -6.152E+02   -7.505E+01   -2.930E+01   uE     Blade Rosette Strain
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Test name: PBT15

Channel  Minimum     Mean        Maximum     Units Channel Desciption
---------------------------------------------------------------------------
1BD1     -9.875E+01  -3.026E+01  -1.833E+00  mm    Blade Displacement
1BD2     -7.814E+01  -4.295E+01  -4.966E+00  mm    Blade Displacement
1BD3     -3.409E+01  -1.061E+01  -2.580E-01  mm    Blade Displacement
1APR1     1.506E+00   1.566E+01   2.648E+01  MPa   Actuator Retract Pressure
1APE1     4.855E-01   1.024E+01   1.703E+01  MPa   Actuator Extend Pressure
1APR2     3.779E+00   1.534E+01   2.225E+01  MPa   Actuator Retract Pressure
1APE2     2.145E+00   9.674E+00   1.418E+01  MPa   Actuator Extend Pressure
1APR3     6.680E-02   1.617E+01   2.613E+01  MPa   Actuator Retract Pressure
1APE3     5.853E-01   9.797E+00   1.648E+01  MPa   Actuator Extend Pressure
1BP1     -6.716E-02  -3.019E-02   6.671E-02  MPa   Blade Surface Pressure
1BP2     -9.989E-02   5.136E-02   5.696E-01  MPa   Blade Surface Pressure
1BP3     -1.346E-01   3.474E+00   2.900E+01  MPa   Blade Surface Pressure
1BP4      1.073E-05   1.091E-01   1.073E+00  MPa   Blade Surface Pressure
1BP5     -3.215E-04   7.502E-02   8.704E-01  MPa   Blade Surface Pressure
1RAMP    -3.906E-02   5.532E-01   2.944E+00   V    Command
1BR1B    -5.000E+03  -3.557E+03  -1.270E+02  uE    Blade Rosette Strain
1AD1      1.335E+02   1.663E+02   2.964E+02  mm    Actuator Displacement
1AD2      1.260E+02   1.583E+02   2.860E+02  mm    Actuator Displacement
1AD3      1.377E+02   1.696E+02   2.968E+02  mm    Actuator Displacement
1BR1A    -5.000E+03  -2.747E+03  -8.789E+01  uE    Blade Rosette Strain
1BR2A     3.662E+01   1.283E+03   2.844E+03  uE    Blade Rosette Strain
1FSG3     3.418E+01   3.964E+02   1.436E+03  uE    Frame Girder Strain
1BS7     -4.252E+03  -1.242E+03  -5.859E+01  uE    Blade Single-Axis Strain
1BS8     -5.000E+03  -2.332E+03  -1.074E+02  uE    Blade Single-Axis Strain
1BS9      2.686E+01   1.945E+03   4.998E+03  uE    Blade Single-Axis Strain
1BS1     -4.712E+02  -4.311E+01   6.104E+01  uE    Blade Single-Axis Strain
1BR2B     1.294E+02   3.877E+03   4.998E+03  uE    Blade Rosette Strain
1BS3     -3.408E+03  -9.555E+02  -5.371E+01  uE    Blade Single-Axis Strain
1BS4     -4.001E+03  -9.849E+02  -5.615E+01  uE    Blade Single-Axis Strain
1BS2     -4.614E+02  -8.487E+01   9.766E+00  uE    Blade Single-Axis Strain
1BR2C     6.346E+01   3.333E+03   4.709E+03  uE    Blade Rosette Strain
1BR1C    -2.847E+03  -1.287E+03  -5.859E+01  uE    Blade Rosette Strain
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Test name: PBT16

Channel  Minimum      Mean         Maximum     Units  Channel Desciption
-------------------------------------------------------------------------------

1BD1     -2.960E+01   -2.920E+01   -2.881E+01   mm     Blade Displacement
1BD2      5.824E+01    5.922E+01    6.060E+01   mm     Blade Displacement
1BD3     -1.022E+01   -9.888E+00   -9.437E+00   mm     Blade Displacement
1APR1     8.359E-02    1.063E-01    1.338E-01   MPa    Actuator Retract Pressure
1APE1    -1.686E-02   -2.828E-03    1.663E-02   MPa    Actuator Extend Pressure
1APR2    -3.392E-02   -1.995E-02   -3.278E-04   MPa    Actuator Retract Pressure
1APE2     6.703E-02    9.421E-02    1.173E-01   MPa    Actuator Extend Pressure
1APR3     6.680E-02    1.000E-01    1.171E-01   MPa    Actuator Retract Pressure
1APE3    -1.706E-02    6.191E-03    3.314E-02   MPa    Actuator Extend Pressure
1BP1     -6.716E-02   -2.384E-02   -2.249E-04   MPa    Blade Surface Pressure
1BP2     -1.334E-01    4.903E-02    5.027E-01   MPa    Blade Surface Pressure
1BP3     -1.011E-01   -6.589E-02   -4.614E-04   MPa    Blade Surface Pressure
1BP4     -3.351E-02    6.043E-02    1.676E-01   MPa    Blade Surface Pressure
1BP5     -3.381E-02    6.539E-02    1.671E-01   MPa    Blade Surface Pressure
1RAMP    -1.953E-02   -1.953E-02   -1.953E-02    V     Command
1BR1B    -1.000E+03   -1.000E+03   -1.000E+03   uE     Blade Rosette Strain
1AD1      2.108E+00    2.313E+00    2.371E+00   mm     Actuator Displacement
1AD2      2.356E+00    2.618E+00    2.618E+00   mm     Actuator Displacement
1AD3      3.406E+00    3.667E+00    3.930E+00   mm     Actuator Displacement
1BR1A    -1.000E+03   -1.000E+03   -1.000E+03   uE     Blade Rosette Strain
1BR2A    -6.836E+00    2.388E-01    9.277E+00   uE     Blade Rosette Strain
1FSG3    -2.197E+01   -2.012E+00    1.221E+01   uE     Frame Girder Strain
1BS7     -7.129E+01    1.948E+00    6.885E+01   uE     Blade Single-Axis Strain
1BS8     -8.110E+02   -7.618E+02   -7.041E+02   uE     Blade Single-Axis Strain
1BS9      9.995E+02    9.995E+02    9.995E+02   uE     Blade Single-Axis Strain
1BS1     -6.201E+01    2.719E+00    8.545E+01   uE     Blade Single-Axis Strain
1BR2B    -1.000E+03   -1.194E+02   -9.717E+01   uE     Blade Rosette Strain
1BS3     -6.592E+01    8.735E-01    3.076E+01   uE     Blade Single-Axis Strain
1BS4     -4.932E+01   -2.095E+00    3.613E+01   uE     Blade Single-Axis Strain
1BS2     -9.229E+01    1.216E+00    8.350E+01   uE     Blade Single-Axis Strain
1BR2C     7.114E+02    7.114E+02    7.114E+02   uE     Blade Rosette Strain
1BR1C    -4.834E+01    4.019E+00    3.027E+01   uE     Blade Rosette Strain
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Test name: PBT17

Channel	Minimum	Mean	Maximum	Units	Channel Desciption
1BD1	-2.960E+01	-2.919E+01	-2.881E+01	mm	Blade Displacement
1BD2	5.876E+01	5.940E+01	6.034E+01	mm	Blade Displacement
1BD3	-1.022E+01	-9.900E+00	-9.699E+00	mm	Blade Displacement
1APR1	8.359E-02	1.021E-01	1.338E-01	MPa	Actuator Retract Pressure
1APE1	-1.686E-02	-2.747E-03	1.663E-02	MPa	Actuator Extend Pressure
1APR2	-5.071E-02	-2.056E-02	-3.278E-04	MPa	Actuator Retract Pressure
1APE2	6.703E-02	9.145E-02	1.173E-01	MPa	Actuator Extend Pressure
1APR3	6.680E-02	9.676E-02	1.171E-01	MPa	Actuator Retract Pressure
1APE3	-1.706E-02	5.871E-03	3.314E-02	MPa	Actuator Extend Pressure
1BP1	-6.716E-02	-2.700E-02	-2.249E-04	MPa	Blade Surface Pressure
1BP2	-1.668E-01	4.816E-02	4.692E-01	MPa	Blade Surface Pressure
1BP3	-1.011E-01	-6.726E-02	-3.399E-02	MPa	Blade Surface Pressure
1BP4	-3.351E-02	5.823E-02	2.011E-01	MPa	Blade Surface Pressure
1BP5	-3.381E-02	6.325E-02	1.671E-01	MPa	Blade Surface Pressure
1RAMP	-1.953E-02	-1.953E-02	-1.953E-02	V	Command
1BR1B	-1.000E+03	-1.000E+03	-1.000E+03	uE	Blade Rosette Strain
1AD1	2.108E+00	2.339E+00	2.371E+00	mm	Actuator Displacement
1AD2	2.618E+00	2.618E+00	2.618E+00	mm	Actuator Displacement
1AD3	3.406E+00	3.667E+00	3.668E+00	mm	Actuator Displacement
1BR1A	-1.000E+03	-1.000E+03	-1.000E+03	uE	Blade Rosette Strain
1BR2A	-5.371E+00	9.017E-02	5.859E+00	uE	Blade Rosette Strain
1FSG3	-1.465E-01	-1.293E+00	1.221E+01	uE	Frame Girder Strain
1BS7	-5.855E+01	2.381E+00	5.420E+01	uE	Blade Single-Axis Strain
1BS8	-7.979E+02	-7.612E+02	-7.227E+02	uE	Blade Single-Axis Strain
1BS9	9.995E+02	9.995E+02	9.995E+02	uE	Blade Single-Axis Strain
1BS1	-8.398E+01	3.028E+00	1.284E+02	uE	Blade Single-Axis Strain
1BR2B	-1.000E+03	-1.193E+02	-8.691E+01	uE	Blade Rosette Strain
1BS3	-3.564E+01	1.225E+00	5.371E+01	uE	Blade Single-Axis Strain
1BS4	-4.102E+01	-1.499E+00	3.711E+01	uE	Blade Single-Axis Strain
1BS2	-6.201E+01	1.749E+00	5.566E+01	uE	Blade Single-Axis Strain
1BR2C	7.114E+02	7.114E+02	7.114E+02	uE	Blade Rosette Strain
1BR1C	-1.465E+01	4.668E+00	4.541E+01	uE	Blade Rosette Strain

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Test name: PBT18

Channel  Minimum     Mean        Maximum     Units  Channel Desciption
------------------------------------------------------------------------------
1BD1     -1.082E+02  -8.546E+01  -2.881E+01  mm     Blade Displacement
1BD2     -9.964E+01  -5.355E+01   5.981E+01  mm     Blade Displacement
1BD3     -3.120E+01  -2.555E+01  -9.437E+00  mm     Blade Displacement
1APR1     2.894E+00   7.589E+00   1.359E+01  MPa    Actuator Retract Pressure
1APE1     3.265E+00   7.618E+00   9.996E+00  MPa    Actuator Extend Pressure
1APR2     3.124E+00   6.936E+00   1.471E+01  MPa    Actuator Retract Pressure
1APE2     3.938E+00   7.459E+00   9.518E+00  MPa    Actuator Extend Pressure
1APR3     3.033E+00   7.498E+00   1.148E+01  MPa    Actuator Retract Pressure
1APE3     3.630E+00   7.746E+00   1.123E+01  MPa    Actuator Extend Pressure
1BP1     -1.676E-01  -4.316E-02   6.671E-02  MPa    Blade Surface Pressure
1BP2     -6.642E-02   5.150E-02   1.679E-01  MPa    Blade Surface Pressure
1BP3     -1.681E-01   2.076E+00   5.800E+00  MPa    Blade Surface Pressure
1BP4     -3.351E-02   6.462E-02   1.676E-01  MPa    Blade Surface Pressure
1BP5     -6.730E-02   6.584E-02   1.671E-01  MPa    Blade Surface Pressure
1RAMP    -4.883E-02   3.841E+00   4.951E+00   V     Command
1BR1B    -6.001E+03  -4.641E+03  -1.558E+03  uE     Blade Rosette Strain
1AD1      3.424E+00   2.136E+02   2.758E+02  mm     Actuator Displacement
1AD2      3.666E+00   2.102E+02   2.711E+02  mm     Actuator Displacement
1AD3      5.238E+00   2.114E+02   2.722E+02  mm     Actuator Displacement
1BR1A    -4.331E+03  -3.405E+03  -1.172E+03  uE     Blade Rosette Strain
1BR2A    -3.418E+01   1.883E+02   3.223E+02  uE     Blade Rosette Strain
1FSG3    -1.221E+01   6.007E+02   8.618E+02  uE     Frame Girder Strain
1BS7     -8.018E+03  -5.334E+03   1.465E+01  uE     Blade Single-Axis Strain
1BS8     -5.410E+03  -3.960E+03  -7.666E+02  uE     Blade Single-Axis Strain
1BS9      1.162E+03   4.500E+03   6.055E+03  uE     Blade Single-Axis Strain
1BS1     -3.013E+03  -2.073E+03   2.441E+01  uE     Blade Single-Axis Strain
1BR2B    -4.395E+01   3.660E+03   5.234E+03  uE     Blade Rosette Strain
1BS3     -1.000E+04  -5.077E+03   2.002E+03  uE     Blade Single-Axis Strain
1BS4     -1.000E+04  -7.014E+03   1.685E+03  uE     Blade Single-Axis Strain
1BS2     -4.146E+03  -2.935E+03   3.418E+01  uE     Blade Single-Axis Strain
1BR2C     2.129E+03   4.767E+03   5.918E+03  uE     Blade Rosette Strain
1BR1C    -1.343E+03  -7.490E+02   1.660E+02  uE     Blade Rosette Strain
```

Test name: PBT19

Channel	Minimum	Mean	Maximum	Units	Channel Desciption
1BD1	-1.857E+02	-7.682E+01	-2.777E+01	mm	Blade Displacement
1BD2	-3.745E+02	-1.335E+02	3.960E+01	mm	Blade Displacement
1BD3	-1.872E+02	-1.778E+01	1.053E+00	mm	Blade Displacement
1APR1	-5.026E-02	3.159E+00	1.676E+01	MPa	Actuator Retract Pressure
1APE1	-1.686E-02	3.001E+00	9.243E+00	MPa	Actuator Extend Pressure
1APR2	-1.011E-01	3.196E+00	1.933E+01	MPa	Actuator Retract Pressure
1APE2	-1.005E-01	3.223E+00	1.150E+01	MPa	Actuator Extend Pressure
1APR3	-1.008E-01	2.733E+00	1.734E+01	MPa	Actuator Retract Pressure
1APE3	-1.676E-01	3.291E+00	1.186E+01	MPa	Actuator Extend Pressure
1BP1	-1.038E+00	-2.957E-02	5.688E-01	MPa	Blade Surface Pressure
1BP2	-1.472E+00	1.015E-01	4.419E+00	MPa	Blade Surface Pressure
1BP3	-6.711E-01	3.500E-02	1.274E+00	MPa	Blade Surface Pressure
1BP4	-4.693E-01	6.570E-02	3.319E+00	MPa	Blade Surface Pressure
1BP5	-5.027E-01	6.206E-02	3.449E+00	MPa	Blade Surface Pressure
1RAMP	-1.025E-01	1.715E+00	4.995E+00	V	Command
1BR1B	-1.000E+04	-4.783E+03	-6.885E+02	uE	Blade Rosette Strain
1AD1	2.106E-03	2.529E+02	4.206E+02	mm	Actuator Displacement
1AD2	-5.028E-04	2.565E+02	3.847E+02	mm	Actuator Displacement
1AD3	-7.826E+01	4.151E+01	4.508E+02	mm	Actuator Displacement
1BR1A	-6.245E+03	-3.157E+03	-1.440E+03	uE	Blade Rosette Strain
1BR2A	-1.514E+02	6.327E+01	3.271E+02	uE	Blade Rosette Strain
1FSG3	-1.685E+02	2.455E+02	1.028E+03	uE	Frame Girder Strain
1BS7	-8.325E+03	-3.351E+03	1.953E+01	uE	Blade Single-Axis Strain
1BS8	-8.306E+03	-4.108E+03	-1.650E+03	uE	Blade Single-Axis Strain
1BS9	-1.030E+03	4.904E+03	9.995E+03	uE	Blade Single-Axis Strain
1BS1	-6.113E+03	-1.436E+03	1.807E+03	uE	Blade Single-Axis Strain
1BR2B	-2.930E+01	2.773E+03	7.813E+03	uE	Blade Rosette Strain
1BS3	-1.000E+04	-4.355E+03	1.987E+03	uE	Blade Single-Axis Strain
1BS4	-1.000E+04	-5.098E+03	1.567E+03	uE	Blade Single-Axis Strain
1BS2	-4.580E+03	-1.613E+03	3.906E+01	uE	Blade Single-Axis Strain
1BR2C	2.485E+03	4.437E+03	8.066E+03	uE	Blade Rosette Strain
1BR1C	-2.144E+03	-7.102E+02	1.270E+02	uE	Blade Rosette Strain

APPENDIX A.9

Equipment Specifications

Equipment Specifications

Electronic

Computer	Hewlett Packard	310
Ram		3 megabyte
A/D Converter	Infotek	
Plotter	HP	
Pointer	HP 2450	
Disk Drive	HP	
Ramp Generator	Wavetek 175	
Strain Gauge Signal Conditioning	Visnay 2120	

Sensors

Strain Gauges	Micromeasurements	CEA-09-250UR-350
	Micromeasurements	CEA-09-500UW-350
Pressure Transducers	Psi tronic-5000-10,000	
	Psi tronic-5000-5,000	
Displacement	Celesco	PT-101-20A

Hydraulic

Special purpose triple hydraulic actuator skid

Maximum operating pressure		42 MPa
Maximum actuator velocity		150 mm/s
Capacity at start, per actuator		4.5 MN
Servo Valves	Moog ____	

Air over oil piston accumulators

5000 psi air compressor

5000 psi oil compressor

2100 SYSTEM

Strain Gage Conditioner
and
Amplifier System

– Instruction Manual –

MEASUREMENTS GROUP

INSTRUMENTS DIVISION
INTERTECHNOLOGY
LIMITED
1 SCARSDALE ROAD, DON MILLS, ONT. M3B 2R2 ☎ (416) 445-5500

SECTION 1
DESCRIPTION

GENERAL

1.1 The Series 2100 modules comprise a multichannel system for generating conditioned high-level signals from strain gage inputs for display or recording on external equipment. A system would be comprised of:

a) One or more 2-channel 2120 Strain Gage Conditioners;

b) One or more 2110 Power Supplies (each Power Supply will handle up to 10 channels; i.e., five 2120 Conditioner/Amplifiers); and,

c) One or more rack adapters or cabinets, complete with wiring, to accept the above modules.

1.2 The principal features of the system include:

... Independently variable and regulated excitation for each channel (1 to 12 Vdc).

... Independently continuously variable gain (100 to 2100) for each channel.

... Bridge-completion components to accept quarter- (120Ω and 350Ω), half- and full-bridge inputs to each channel as standard.

... LED null indicators on each channel – always active.

... 100 mA output as standard.

... All supplies and outputs short-circuit proof with current limiting.

... Compact packaging – 10 channels in 5-¼ in x 19 in rack space.

SPECIFICATIONS

All specifications nominal or typical at 23°C unless noted.

1.3 2120 STRAIN GAGE CONDITIONER

Note: These specifications apply for each of two independent channels per module.

INPUTS	Quarter (120Ω and 350Ω), half and full bridge. Quarter-bridge dummy resistors provided.
BRIDGE EXCITATION	1 to 12 Vdc (adjustable for each channel) with 120Ω full bridge load. Short-circuit current: less than 40 mA. Ripple, noise, and 10% line change: 2 mV max. Load regulation: ±0.2% no-load to 120Ω load.
BRIDGE BALANCE	±2000 $\mu\epsilon$ (quarter, half, or 350Ω full bridge); range can be changed by internal resistance change.
CALIBRATION	Two-position (center off) toggle switch. As delivered: ±1000 $\mu\epsilon$ ±1% at GF = 2 (see also Section 3).
AMP GAIN	100 to 2100 continuously adjustable. Gain equal to twice dial reading (±2%).
BANDPASS	dc to 5 kHz (min): ±0.5 dB (±5%) dc to 15 kHz: ±3 dB
AMP INPUT	Temperature coefficient: ±2 μV RTI/°C (max). Warm-up: 25 μV RTI over 30 minutes. Noise and drift (pk-pk): dc – 10 μV RTI/day; 0.01 to 100 Hz – 3 μV RTI (max); 1 Hz up – 10 μV RTI (max). Input impedance: >25 MΩ differential or common mode (balance limit resistor removed). CMR: dc – 120 dB (min); 0 to 500 Hz – 100 dB Input bias: +0.1 μA each input.
OUTPUT	±10 V (min) at 30 mA; ±50 mA (min) into 150Ω load; ±100mA (min) into 15Ω load. Current limit: 120 mA. Linearity: ±0.05% at dc.
SIZE & WEIGHT	5.25 in H x 2.94 in W x 10.97 in D (133 mm x 75 mm x 279 mm) 2.2 lb (1.0 kg)

1.4 2110 POWER SUPPLY

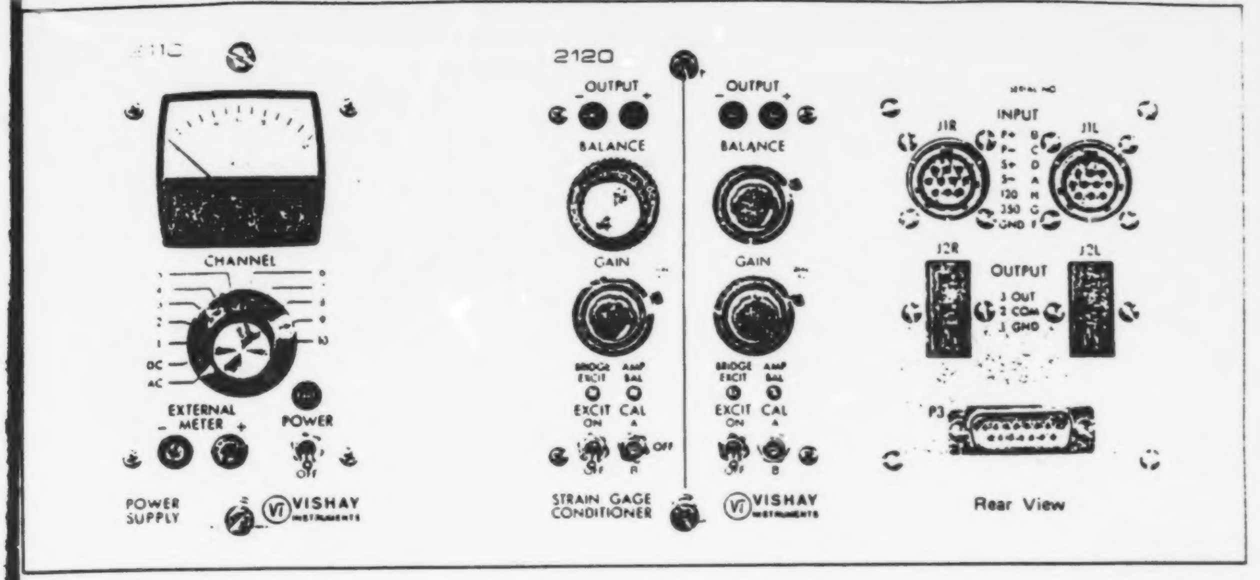
OUTPUTS	±15 V at 1.2 A and +17.5 V at 1.1 A; all regulators current-limited against overload.
INPUT	107, 115, 214, 230 Vac ±10% (selected internally); 50-60 Hz. Power: 40 W typical, 100 W max.
METER	0 to 12 Vdc (with switch) to read bridge excitation. Also ac input and dc output to/no-go monitor.
SIZE & WEIGHT	5.25 in H x 2.44 in W x 12.34 in D (133 mm x 62 mm x 313 mm) 6.7 lb (3.1 kg)

1.5 2150 RACK ADAPTER

APPLICATION	Fits standard 19-in (483-mm) electronic equipment rack. Accepts one 2110 Power Supply and one to five 2120 Strain Gage Conditioners. Completely wired.
POWER	2-ft (0.6-m) 3-wire line cord; 10-ft (3-m) extension available. Fuse: 1 A size 3 AG (32 mm x 6.4 mm dia.). Receptacle to accept line cord from adjacent 2150 Rack Adapter.
SIZE & WEIGHT	5.25 in H x 19 in W x 12.82 in D overall (133 mm x 483 mm x 325 mm) 6.6 lb (3.0 kg)

1.6 2160 PORTABLE ENCLOSURE

DESCRIPTION	Completely self-contained adapter and cabinet with all wiring for two or four channels. Accepts one 2110 Power Supply and one or two 2120 Strain Gage Conditioners.
POWER	8-ft (2.4-m) detachable 3-wire cord. Fuse: 1 A size 3 AG (32 mm x 6.4 mm dia.).
SIZE & WEIGHT	5.50 in H x 8.75 in W x 13.13 in D (140 mm x 222 mm x 333 mm) 5.2 lb (2.4 kg).



CONTROLS

1.7 2110 POWER SUPPLY

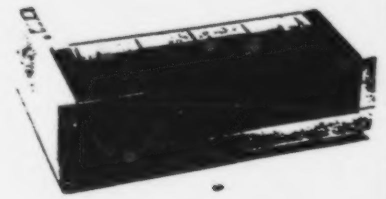
BRIDGE VOLTS Meter	Displays the voltage on each input bridge (as selected by CHANNEL selector). Also used to monitor ac line and dc outputs of Power Supply (see below).
CHANNEL Selector	Positions 1 to 10 select channel to display bridge excitation on Meter ("1" is channel farthest to left in cabinet, etc). The DC position monitors a mixed output from the +15, −15, and +17.5 V power supplies and should always read on the "DC" line at "10" on the Meter. The AC position monitors the peak-to-peak ac line input (at a fixed transformer tap). A reading anywhere in the band from 9 to 11 on the Meter indicates that the input voltage is proper for the selected transformer tap (see paragraph 2.5). No reading indicates the equipment is ungrounded; noticeable needle vibration indicates reversal of the ac input line.
EXTERNAL METER Jacks	Supplies Meter voltage to an external meter if desired for precise adjustment of bridge supply voltages.
POWER Switch	The main power switch for this supply and all Conditioners connected to it. (The pilot lamp may take several seconds to extinguish when the power is turned off.)

1.8 2120 STRAIN GAGE CONDITIONER (one channel described; both identical and independent).

OUTPUT Lamps	LED indicators always monitoring amplifier output. Primarily used to adjust AMP BAL and Bridge BALANCE. (Fully lit with 0.07 V output.)
BALANCE Control	A 10-turn potentiometer to adjust bridge balance. Normal range ±2000 $\mu\epsilon$. (See paragraph 2.26 to extend range.) EXCIT must be ON to set bridge balance.
GAIN Control	A 10-turn potentiometer to adjust amplifier gain. The nominal gain equals twice the dial reading (e.g., with the dial set at 500 the gain is approximately 1000). Gain is adjustable from 100 to 2100 (050 to 1050 on GAIN dial).
GAGE EXCIT	A 22-turn trimmer to adjust bridge excitation from 1 to 12 Vdc. The actual setting is monitored on the Meter and the EXTERNAL METER jacks on the 2110 Power Supply (the proper channel must be selected).
AMP BAL	A 22-turn trimmer to adjust the amplifier balance. (EXCIT should be OFF when this is done.) Thermal EMF's in the bridge may also affect this balance.
EXCIT switch	A toggle switch controlling the excitation to the input bridge. (Any amplifier output with EXCIT at OFF is dc amplifier offset, thermal EMF from the bridge or ac pickup in the wiring.)
CAL Switch	A 2-position (with center off) toggle switch to shunt-calibrate the input bridge. As delivered, "A" simulates +1000 $\mu\epsilon$, and "B" simulates −1000 $\mu\epsilon$ by shunting the internal 350Ω half bridge. Many other arrangements possible by internal-resistor and jumper changes (see Section 3).
INPUT receptacle (rear panel)	A 10-pin quarter-turn connector to connect input gage(s). (Quarter, half and full bridges can be accepted simply by using the appropriate pins. See paragraph 2.11 for details.) Mating connector supplied.
OUTPUT receptacle (rear panel)	A 3-pin connector delivers the amplifier output (±10 V or ±100 mA). Mating connector supplied.

HP 2225 Family
ThinkJet Printers

HEWLETT PACKARD



The low-cost HP 2225 family of personal printers provides fast, quiet printing for office, factory, home, or on-the-go. For permanent copies and portable printing, for high-quality, professional-looking text, the HP 2225 Family offers an exceptional solution via an all-new approach to ink-jet printing.

Simplicity of Design for User Convenience

The HP 2225 Family features a new and unique high-technology ink-jet print head system that is encased in a single disposable cartridge. There are no reservoirs to fill and virtually no mess. When the print head is empty, after about 500 pages of normal printing, you simply open the front window of the printer, pull a tab down, lift the old cartridge out, and insert the new one in place. Push the tab back up, close the print window; and you're off again.

Printing Flexibility

For highlighting and print variation, you can choose from four different print pitches. And you can print your text in boldface or underline in just one pass without sacrificing throughput. In addition, you get clear, distinct graphics with up to 192 x 96 dots per inch resolution.

Since the printer utilizes both friction feed and pin feed, you can use either single sheets or continuous fanfold paper depending on your application needs. The adjustable paper-feed mechanism allows you to use either 8½ x 11-inch or 21.0 x 29.7-centimeter (A-4 size) paper.

Features:	Benefits and Advantages:
• 150-cps ink-jet printing	Delivers high throughput and permanent copies of your memos, graphics, reports, and spreadsheets.
• 11 x 12 dot-matrix character cell	Your printed text is easy to read and professional looking.
• Quiet 50 dBA printing	Suitable for any environment because noise is not a factor.
• Comprehensive print features –four print pitches –underline and bold –Roman8 –printable control codes	Allows you to highlight and vary your output to meet your different pri
• Disposable print head	Qu acc get wi
• Compact and lightweight	It r of on
• Portable operation (HP2225B)	Ut tha no
• Variety of interfaces	Yo of Pa In fe
• Pin or friction feed	Allows you to use continuous fanfold paper or cut sheets.
• Graphics	Produces permanent copies of your graphics displays.

Print Sample

Print quality is enhanced over common dot matrix printers by an 11 x 12 character cell which provides high resolution characters in boldface or underline modes and four print pitches as shown here.

```
Compressed (142 characters/line)
Normal (80 characters/line)
Expanded compressed (71 characters/line)
Expanded(40 characters/line)
```

INFOTEK AD-200

2 SPECIFICATIONS

2.1 GENERAL

12 BIT Resolution

16 Single ended / 8 differential inputs

0 to 55 Degrees Celcius

Common mode rejection @ 120 Hz

> 75 db @ hardware gain = 1
> 80 db @ hardware gain = 4
> 85 db @ hardware gain = 10

2.2 INPUT (ANALOG)

Range (+/- Volts DC) See table below

	hardware gain		
Programmed gain	1	4	10
1	5.000	1.250	0.500
2	2.500	0.625	0.250
5	1.000	0.250	0.100
10	0.500	0.125	0.050

Common mode range +/- 5.0 Volts

Resistance > 10E10 Ohms

Capacitance < 150 Pf

Overvoltage +/- 20.0 Volts

Current < 10 Nanoamps

2.3 THROUGHPUT

Maximum settling times to within 1 LSB (See table below) time is in microseconds (equivalent sample rate in 1000 samples/second in brackets)

Condition	Hardware gain 1	4	10
Step response (single)	3.3	4.0	5.0
Step response (burst)	4.8 (208)	5.0 (200)	5.0 (200)
Channel-to-Channel	5.0 (200)	5.0 (200)	7.5 (133)
Channel/gain to Channel/gain	6.0 (166)	7.5 (133)	12.5 (80)

Bandwidth > 300 KHz

2.4 ACCURACY

Absolute error (Hardware gain = Programmed gain = 1)
(see note 1)

0.15% of reading + 3 LSB's

Gain Drift < 0.15%

Relative gain error (gain non-linearity) < 0.05%

Offset drift error (in LSB's) See table below
(see note 1)

	Hardware gain		
Programmed gain	1	4	10
1	3	5	7
2	3	5	9
5	4	7	13
10	5	10	20

Relative offset error (relative to hardware gain = 1)
(see notes 1 and 2)

< 12 LSB's @ hardware gain = 4

< 29 LSB's @ hardware gain = 10

Linearity < 1 LSB

Noise (RMS in LSB's) (See table below)
These figures may be significantly higher for the 9816

	Hardware gain		
Programmed gain	1	4	10
1	0.6	0.7	1.0
2	0.8	1.2	1.5
5	0.8	2.0	3.0
10	1.0	3.0	5.0

2.5 DIGITAL

Timebase	Delay	100 nanoseconds to 0.500 seconds in 50 nanosecond steps.
	Period	3000 nanoseconds to 0.500 seconds in 50 nanosecond steps.
	Clock	0.005% stability and accuracy

2.6 POWER REQUIREMENTS

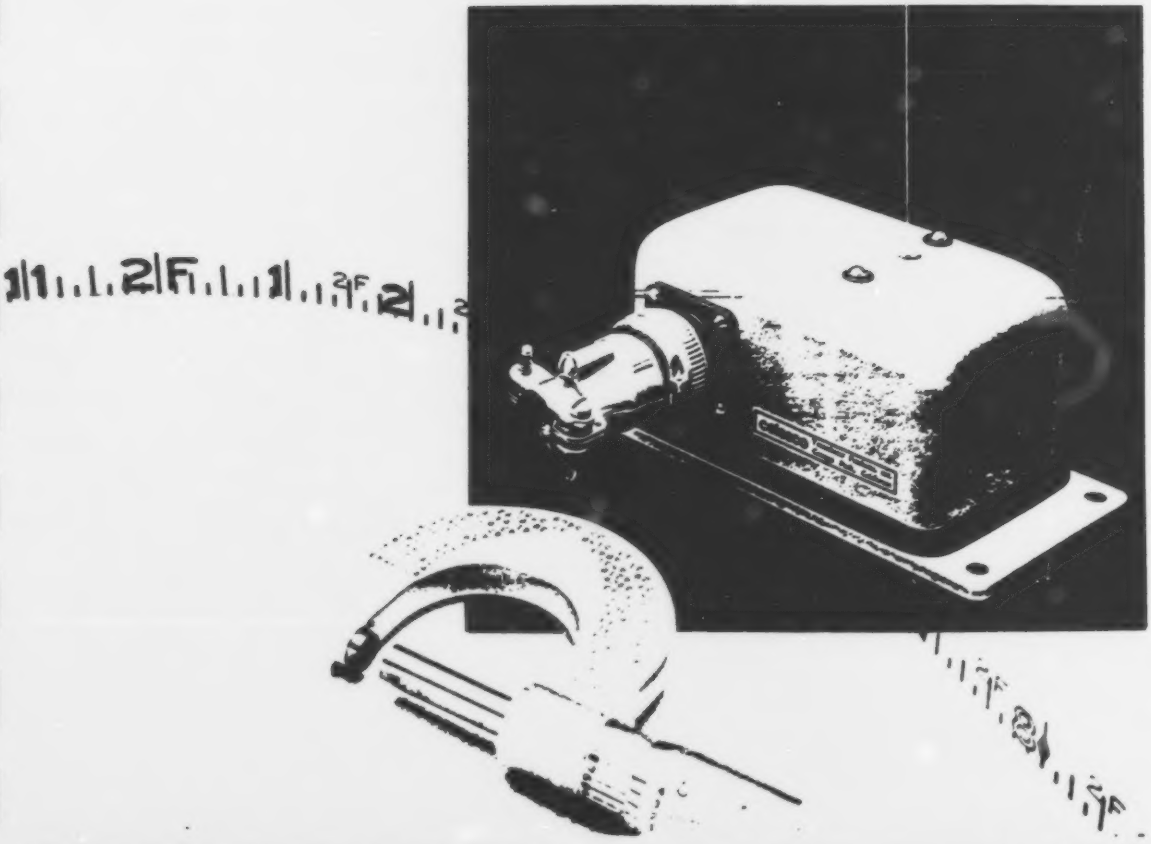
+5 Volts	1.0 Amps
+12 Volts	40 Milliamps
-12 Volts	58 Milliamps

NOTE 1: Offsets can be eliminated through software by measuring a grounded input and adjusting readings accordingly.

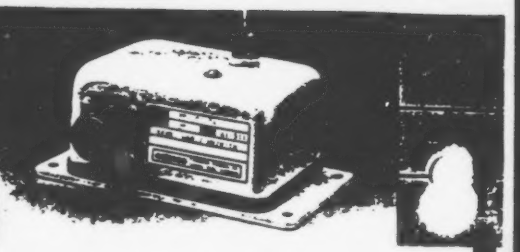
NOTE 2: Offset error can be adjusted to zero for any Hardware gain. Factory calibration zeros the offset for hardware gain = 1.

Celesco Transducer Products, Inc.

Celesco means measurement.



PT101
Position/Displacement Transducer



The position measurement workhorse.

The PT101 is our most widely used transducer. Such diverse applications as positioning shutter dampers for draft control, testing automotive suspension systems and monitoring lateral drift in space shuttle launching operations are common. Designed for linear measurements up to 500 inches, it provides a voltage output by means of a precision potentiometer. A more rugged version is available for use in extreme environments. This instrument will endure shock of 2,000 G's for six milliseconds and vibration of 10 G's from 10 to 2000 Hz without damage or changes in calibration.

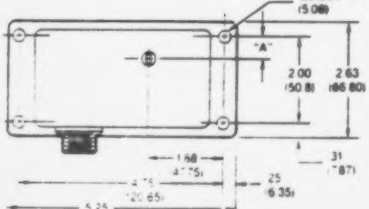
FEATURES:

- 0.1% accuracy standard (most ranges)
- Resolution of 0.001 inch (most ranges)
- Ranges from 0-2 to 0-500 inches full scale
- "A" circuit full scale output approximates input
- "B" circuit simulates wheatstone bridge with zero at midpoint for use with stain gauge signal conditioners

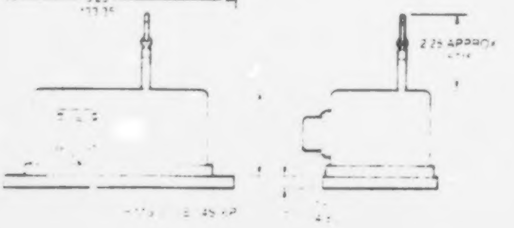
Measurement Range	Position "A" Circuit	Transducer "B" Circuit	Approx. Cable Tension	Max. Cable Acceleration	
Inches	MV/V/Inch	MV/V/Inch	Ounces	Ext. G's	Ret.
2	468.49	1.0536	27	37	25
5	188.51	0.4240	11	7	5
10	94.754	0.2131	27	37	25
15	62.547	0.1407	18	15	10
20	47.377	0.1065	27	37	25
25	38.182	.08587	11	7	5
30	31.317	.07043	18	15	10
40	24.641	.05542	14	12	8
50	19.091	.04294	11	7	5
60	16.342	.03676	9	6	4
75	13.190	.02967	8	5	3
80	12.446	.02799	14	5	3
100	9.8870	.02224	25	7	5
150	6.1763	.01389	16	6	4
200	4.9638	.01116	12	5	3
250	3.8818	.008731	10	5	3
300	3.3107	N.A.	12	5	3
350	2.8162	N.A.	10	5	3
500	1.9777	N.A.	15	5	3

$652

HT-TEMP OPT.
$100



"A" DIM	RANGE
.66 (16.76)	2" 10" 20"
.44 (11.18)	15" 30"
.17 (4.32)	5" 25" 40" 50"



Specifications:

GENERAL

- **Range**[1] .... 0-2 to 0-500 inches
- **Weight** .... 20 ounces (to 50 inch range)
- **Case Material** .... Aluminum
- **Sensing System** .... Precision Potentiometer
- **Electrical Connector** .... MS3102E-14S-6P (Other connectors optional)

ELECTRICAL

- **Input Impedance**
  - **"A" Circuit** .... 500 ohms std. Other options available
  - **"B" Circuit** .... 1100 ohms std. Other options available
- **Output Impedance**
  - **"A" Circuit** .... 138 ohms max. std. Other options available
  - **"B" Circuit** .... 240 ohms std. Other options available
- **Excitation Voltage** .... 25 volts max., AC or DC
- **Insulation Resistance** .... 100 meg ohms min. at 100 VDC

PERFORMANCE

- **Accuracy:**[2]
  - **2 and 5 inch ranges** .... 0.25% F.S. max.
  - **10 and 15 inch ranges** .... 0.15% F.S. max.
  - **20 inch and greater** .... 0.10% F.S. max.
- **Resolution:**
  - **2 and 5 inch ranges** .... 0.08% F.S. max.
  - **10 inch and greater** .... Effectively Infinite
- **Thermal Effects:**[3]
  - **Zero** .... 0.002%/°F
  - **Span** .... 0.002%/°F
- **Sensitivity** .... See Specification Table

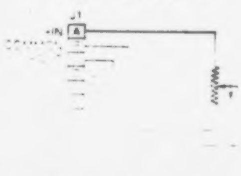
ENVIRONMENTAL

- **Temperature Range** .... 0°F to +200°F (-65°F to +250°F available)
- **Humidity** .... up to 90% RH
- **Shock** .... up to 50 G's. 6 m.s.
- **Vibration** .... up to 10 G's to 2000 Hz

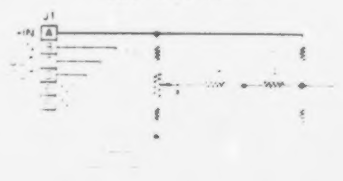
NOTES:

1. See Table for standard ranges. Longer ranges available, consult factory.
2. Repeatability and non-linearity errors included.
3. Over temperature range from 0°F to 200°F.

ELECTRICAL CIRCUIT A



ELECTRICAL CIRCUIT B



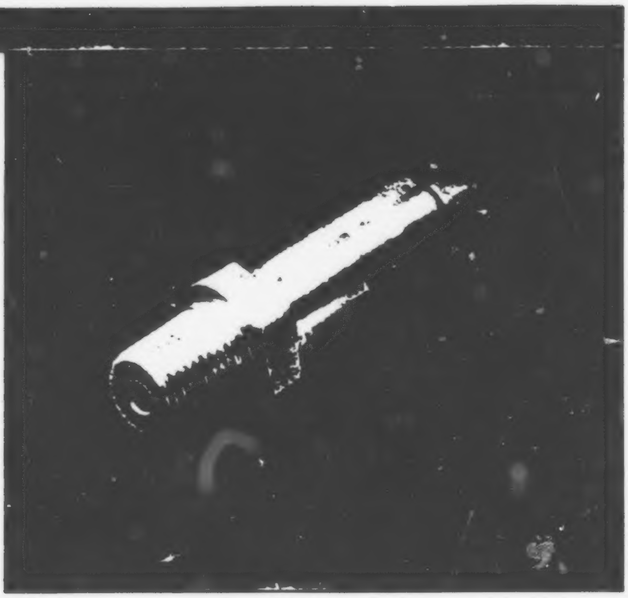
ORDER INFORMATION

MODEL NO	RANGE (IN.)	CIRCUIT
[illegible]	50	A

Ψ PSI-TRONIX

PSI-5000

High Level Output Pressure Transducer



Highly Accurate Pressure Transducer for Minute Pressure Ranges

Features

- Low Cost
- Accuracy (Linearity, Hysteresis, Repeatability): ±.25% F.S. (B.F.S.L.)
- Hybrid Electronics

Description

Strain Gage Transducer Accepts Unregulated Input.

The PSI-5000 offers pressure ranges of 0-15 to 0-10,000 psi, gage or absolute, all stainless steel construction, high burst pressure, and high accuracy of ±.25% F.S. (B.F.S.L.).

The sensor consists of silicon piezoresistive strain gages, mounted on a flat diaphragm, and arranged in a wheatstone bridge configuration. The output is conditioned for 5.0 volts output for all units.

The highly accurate sensor, with hybrid electronics is packaged in a stainless steel housing for use in most environments.

Basic Applications

PSI-5000 is the economical answer for all applications requiring high accuracy over a wide range of pressures. The unit's small size (2 oz.), integrated hybrid electronics, wide operating temperature range (-65° F to +200° F), extreme reliability, durability, and long life, make the PSI-5000 the perfect instrument for most static and dynamic pressure measurement where a high level output signal is desired.

SEE REVERSE SIDE FOR SPECIFICATIONS AND OPTIONS

4509 Runway St., Simi Valley, California 93063 • (805) 584-6617 • (818) 993-9790

Ψ PSI-TRONIX

PSI-5000

High Level Output Pressure Transducer

Specifications

PERFORMANCE

Pressure Ranges: (gage or absolute)	0 to 15, 25, 50, 100, 250, 500, 1000, 3000, 5000, and 10,000 psi
Overpressure:	2x Range
Burst Pressure:	10x full scale or 20,000 psi, whichever is less
Pressure Cavity Volume:	0.025 in³
Output:	5.050 Vdc ±.050 Vdc
Accuracy (linearity, hysteresis, and repeatability):	±.25% of full scale (B.F.S.L.)
Zero Balance:	±1.0% of full scale
Temperature Range:	0-130° F
Thermal Zero Shift:	±0.01% F.S./° F
Thermal Sensitivity Shift:	±0.01% F.S./° F
Resolution:	Infinite
Life:	Millions of cycles

ELECTRICAL

Excitation:	16 to 32 Vdc
Input Impedance:	2800Ω min.
Output/Input:	non-isolated, 3-wire

ENVIRONMENTAL

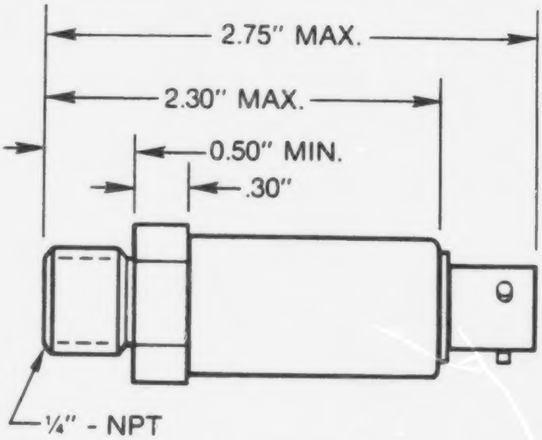
Maximum Temperature Operating Range:	-65° F to +200° F
Compensated Range:	0° F to 130° F

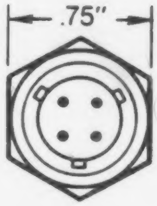
PHYSICAL

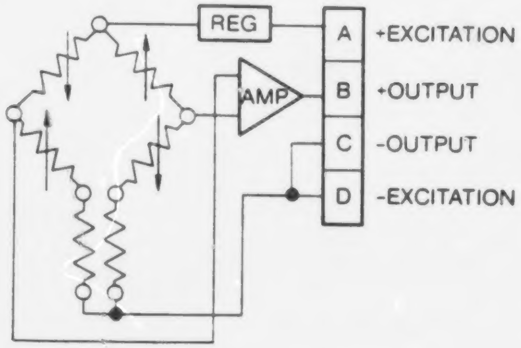
Weight:	2 ounces
Construction Materials:	Stainless Steel 17-4P.H. and 316 S.S.T. (no O-rings)
Media:	Compatible with 17-4P.H. and 316 S.S.T.

Connectors:
Electrical Recptl.: Bendix PT1H-8-4 PN or equivalent
Mating Connector: Bendix PT06A-8-4S (SR) or equivalent
(mating connector not supplied)

Installation Diagrams







Options:

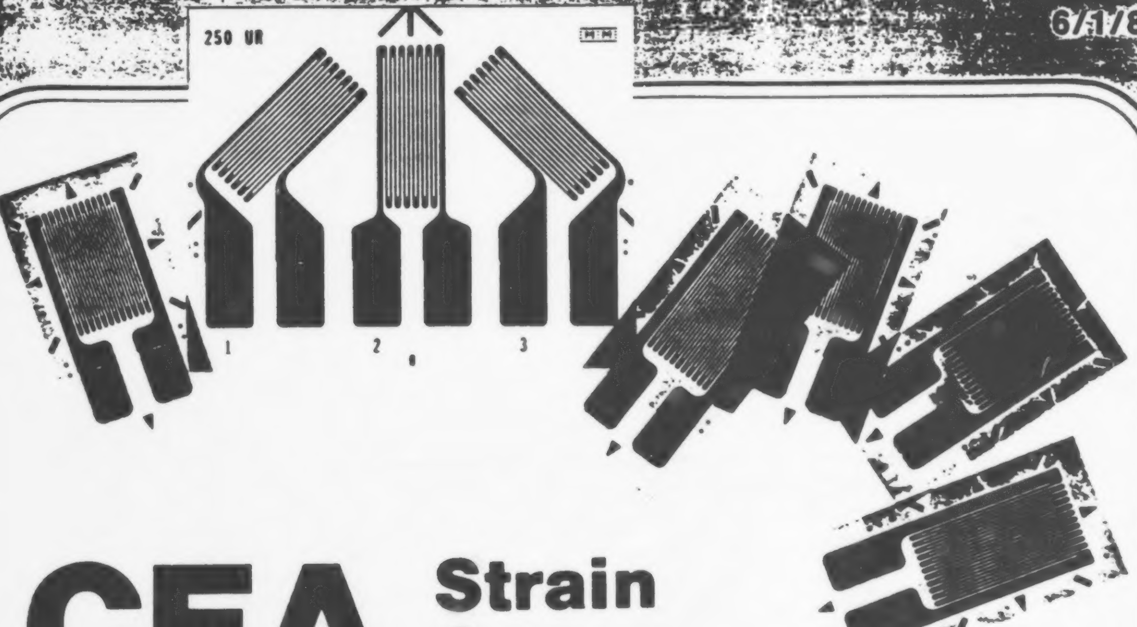
- Special Fittings and excitation on Request
- Consult Factory for Custom Designs for Special Applications

Ordering Information

PSI-5000 — 1000 — G

PSI-5000: Model No.
1000: Pressure Range(psi)
G: G=gage, A=absolute

product M-M bulletin PB-108
6/1/85



CEA Strain Gages

FEATURES

- **Easy to Install**
- **Large Integral Copper-Coated Solder Tabs**
- **Ultra-Thin and Conformable**
- **Pretrimmed Matrix**
- **Completely Encapsulated Grid**

Micro-Measurements CEA-Series Strain Gages are the most widely accepted general-purpose gages in the world today. CEA strain gages are designed for fast, easy installation—no auxiliary terminals required; no integral leadwires to get contaminated by the bonding adhesive. Leadwire installation is accomplished by soldering directly to the large, integral copper-coated tabs. A representative selection of the CEA strain gages available from Micro-Measurements is shown in this bulletin. A complete listing of available CEA gages is included in the Micro-Measurements Catalog 400/Strain Gage Listings.

Pricing for the products shown in this Bulletin is available from your local Measurements Group distributor.

MEASUREMENTS GROUP

MICRO-MEASUREMENTS DIVISION
Measurements Group, Inc.
P.O. Box 27777
Raleigh, North Carolina 27611, USA
Telephone (919) 365-3800 • Telex 802-502 • TWX 510-920-0770

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SPECIFICATIONS

CONSTRUCTION: Fully encapsulated grid with exposed copper-coated tabs.

FOIL ALLOY: Constantan

CARRIER MATRIX: Polyimide

NOMINAL GAGE THICKNESS: Single Plane: 0.0022 in *(0.056 mm)*. Stacked Rosettes: 0.0039 in *(0.099 mm)*.

STRAIN LIMITS: ±3% to ±5% depending upon gage size.

FATIGUE LIFE: $>10^5$ cycles at $\pm 1500 \times 10^{-6}$

TEMPERATURE RANGE: −100° to +400°F *(−75° to +200°C)*. Stacked Rosettes are limited to +150°F *(+65°C)*.

SELF-TEMPERATURE-COMPENSATION (S-T-C): Available for most structural materials. The XX in the gage coding system is replaced with the appropriate S-T-C number required to most closely match the thermal coefficient of expansion (PPM/°F) of the test material. Common S-T-C numbers are 03, 05, 06, 09, 13 and 15.

ORDERING INFORMATION

BASIC ORDERING UNIT: Gages are packaged five to a package. When ordering, please specify the number of *packages* of each gage type.

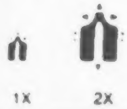
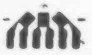
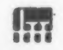
MINIMUM ORDER REQUIREMENTS: Commonly used gage types are normally in stock. The less common gage types are manufactured to order and are subject to Minimum Order Requirements (MOR).

PRICING
Please consult with our local agent or distributor for current pricing.

STOCK STATUS SYMBOLS: To provide a general indication of stock status, the following symbols are used for this bulletin.

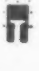
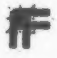
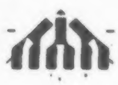
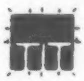
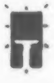
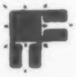
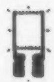
🄰	Widely used gage types stocked in 06 and 13 S-T-C numbers. Other S-T-C numbers may be subject to a minimum order requirement (MOR).
A	Generally in stock in 06 and 13 S-T-C numbers.
B	Less commonly used gage types but frequently in stock.
C	Infrequently used gage types generally requiring an MOR if not in stock.

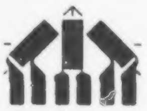
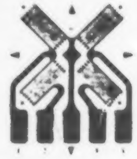
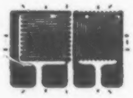
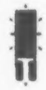
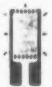
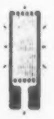
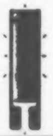
GAGE LISTINGS

GAGE PATTERN Actual size shown. Enlarged when necessary for definition.	GAGE DESIGNATION Insert Desired S-T-C No. in Spaces Marked XX	Stock Status †	RES. IN OHMS	DIMENSIONS ‡ inches / millimetres ES = Each Section CP = Complete Pattern					
				Gage Length	Overall Length	Grid Width	Overall Width	Matrix Length	Matrix Width
015UW	CEA-XX-015UW-120	🄰	120 ±0.3%	0.015	0.140	0.020	0.105	0.24	0.18
 1X 2X				*0.38*	*3.56*	*0.51*	*2.67*	*6.1*	*4.6*
				NOTES: Micro-miniature pattern for high-strain-gradient applications. Exposed solder tab area is 0.06 x 0.04 in *(1.5 x 1.0 mm)*					
032UW	CEA-XX-032UW-120	🄰	120 ±0.3%	0.032	0.180	0.060	0.120	0.27	0.19
				0.81	*4.57*	*1.52*	*3.05*	*6.9*	*4.8*
				NOTES: Short-gage-length pattern for high-strain-gradient applications. Exposed solder tab area is 0.07 x 0.04 in *(1.8 x 1.0 mm)*					
062UR	CEA-XX-062UR-120	A	120 ±0.4%	0.062 ES	0.222 CP	0.062 ES	0.420 CP	0.32	0.48
	CEA-XX-062UR-350	B	350 ±0.4%	*1.57 ES*	*5.64 CP*	*1.57 ES*	*10.67 CP*	*8.1*	*12.2*
				NOTES: Small 45° rectangular single-plane rosette in a compact geometry. Exposed solder tab area is 0.07 x 0.04 in *(1.8 x 1.0 mm)*					
062UT	CEA-XX-062UT-120	A	120 ±0.4%	0.062 ES	0.205 CP	0.080 ES	0.225 CP	0.31	0.31
	CEA-XX-062UT-350	B	350 ±0.4%	*1.57 ES*	*5.21 CP*	*2.03 ES*	*5.72 CP*	*7.9*	*7.9*
				NOTES. Small general-purpose two-element 90° tee rosette. Exposed solder tab area is 0.07 x 0.04 in *(1.8 x 1.0 mm)*					

† See Ordering Information Above. [illegible]

‡ [illegible] Gage Length, Overall Length, Grid Width and Overall Width refer to the actual foil pattern, and do not include alignment marks or backing.

GAGE PATTERN ← Actual size shown. Enlarged when necessary for definition.	GAGE DESIGNATION Insert Desired S-T-C No. in Spaces Marked XX	Stock Status †	RES. IN OHMS	DIMENSIONS ‡ inches / millimetres Gage Length	ES = Each Section Overall Length	CP = Complete Pattern Grid Width	Overall Width	Matrix Length	Matrix Width
062UW	CEA-XX-062UW-120	$\boxed{\text{A}}$	120 ±0.3%	0.062	0.220	0.120	0.120	0.31	0.19
	CEA-XX-062UW-350	$\boxed{\text{A}}$	350 ±0.3%	*1.57*	*5.59*	*3.05*	*3.05*	*7.9*	*4.8*
				**NOTES:** Small general-purpose gage. Exposed solder tab area is 0.07 x 0.04 in *(1.8 x 1.0 mm).*					
062WT	CEA-XX-062WT-120	C	120 ±0.5%	0.062 ES	0.220 CP	0.120 ES	0.220 CP	0.31	0.31
	CEA-XX-062WT-350	C	350 ±0.5%	*1.57 ES*	*5.59 CP*	*3.05 ES*	*5.59 CP*	*7.9*	*7.9*
				**NOTES:** Small two-element 90° 'tee' stacked rosette. Exposed solder tab area is 0.07 x 0.04 in *(1.8 x 1.0 mm).* Maximum operating temperature for stacked CEA rosettes is +150°F *(+65°C).*					
125UR	CEA-XX-125UR-120	$\boxed{\text{A}}$	120 ±0.4%	0.125 ES	0.300 CP	0.060 ES	0.560 CP	0.42	0.62
	CEA-XX-125UR-350	$\boxed{\text{A}}$	350 ±0.4%	*3.18 ES*	*7.62 CP*	*1.52 ES*	*14.22 CP*	*10.7*	*15.7*
				**NOTES:** General-purpose 45° single-plane rosette in a compact geometry. Exposed solder tab area is 0.08 x 0.06 in *(2.0 x 1.5 mm).*					
125UT	CEA-XX-125UT-120	$\boxed{\text{A}}$	120 ±0.4%	0.125 ES	0.325 CP	0.165 ES	0.365 CP	0.42	0.45
	CEA-XX-125UT-350	$\boxed{\text{A}}$	350 ±0.4%	*3.18 ES*	*8.26 CP*	*4.19 ES*	*9.27 CP*	*10.7*	*11.4*
				**NOTES:** Two-element 90° 'tee' rosette for general-purpose use. Exposed solder tab area is 0.10 x 0.07 in *(2.5 x 1.8 mm).*					
125UE	CEA-XX-125UE-120	B	120 ±0.3%	0.125	0.470	0.125	0.125	0.57	0.20
	CEA-XX-125UE-350	B	350 ±0.3%	*3.18*	*11.94*	*3.18*	*3.18*	*14.5*	*5.1*
				NOTES: General-purpose pattern with large tab at each end of grid. Exposed solder tab area is 0.08 x 0.07 in *(2.0 x 1.8 mm).*					
125UN	CEA-XX-125UN-120	$\boxed{\text{A}}$	120 ±0.3%	0.125	0.275	0.100	0.120	0.38	0.19
	CEA-XX-125UN-350	$\boxed{\text{A}}$	350 ±0.3%	*3.18*	*6.99*	*2.54*	*3.05*	*9.7*	*4.8*
				NOTES: General-purpose gage with narrow geometry. Exposed solder tab area is 0.06 x 0.05 in *(1.5 x 1.1 mm).*					
125UW	CEA-XX-125UW-120	$\boxed{\text{A}}$	120 ±0.3%	0.125	0.325	0.180	0.180	0.42	0.27
	CEA-XX-125UW-350	$\boxed{\text{A}}$	350 ±0.3%	*3.18*	*8.26*	*4.57*	*4.57*	*10.7*	*6.9*
				**NOTES:** General-purpose 1/8-in *(3.2-mm)* gage; most widely used of CEA Series. Exposed solder tab area is 0.10 x 0.07 in *(2.5 x 1.8 mm).*					
125WT	CEA-XX-125WT-120	C	120 ±0.5%	0.125 ES	0.325 CP	0.180 ES	0.325 CP	0.42	0.42
	CEA-XX-125WT-350	C	350 ±0.5%	*3.18 ES*	*8.26 CP*	*4.57 ES*	*8.26 CP*	*10.7*	*10.7*
				**NOTES:** Two-element 90° 'tee' stacked rosette. Exposed solder tab area is 0.10 x 0.07 in *(2.5 x 1.8 mm).* Maximum operating temperature for stacked CEA rosettes is +150°F *(+65°C).*					
187UV	CEA-XX-187UV-120	$\boxed{\text{A}}$	120 ±0.4%	0.187 ES	0.560 CP	0.150 ES	0.330 CP	0.62	0.39
	CEA-XX-187UV-350	$\boxed{\text{A}}$	350 ±0.4%	*4.75 ES*	*14.22 CP*	*3.81 ES*	*8.38 CP*	*15.7*	*9.9*
				NOTES: Two-element 90° rosette for torque and shear-strain measurement. Sections have a common electrical connection. Exposed solder tab area is 0.13 x 0.08 in *(3.3 x 2.0 mm).*					
187UW	CEA-XX-187UW-120	B	120 ±0.3%	0.187	0.387	0.180	0.180	0.48	0.27
	CEA-XX-187UW-350	B	350 ±0.3%	*4.75*	*9.83*	*4.57*	*4.57*	*12.2*	*6.9*
				**NOTES:** General-purpose 3/16-in *(4.8-mm)* gage. Exposed solder tab area is 0.10 x 0.07 in *(2.5 x 1.8 mm).*					

GAGE PATTERN Actual size shown. Enlarged when necessary for definition.	GAGE DESIGNATION Insert Desired S-T-C No. in Spaces Marked XX	Stock Status †	RES. IN OHMS	DIMENSIONS ‡ (inches / millimetres) ES = Each Section CP = Complete Pattern Gage Length	Overall Length	Grid Width	Overall Width	Matrix Length	Matrix Width
250UR 	CEA-XX-250UR-120	$\boxed{A}$	120 ±0.4%	0.250 ES	0.500 CP	0.120 ES	0.760 CP	0.65	0.80
	CEA-XX-250UR-350	$\boxed{A}$	350 ±0.4%	*6.35 ES*	*12.70 CP*	*3.05 ES*	*19.30 CP*	*16.5*	*20.3*
				NOTES: Large three-element 45° single-plane rosette. Exposed solder tab area is 0.13 × 0.08 in *(3.3 x 2.0 mm).*					
250US 	CEA-XX-250US-120	B	120 ±0.4%	0.250 ES	0.820 CP	0.120 ES	0.700 CP	0.96	0.80
	CEA-XX-250US-350	B	350 ±0.4%	*6.35 ES*	*20.83 CP*	*3.05 ES*	*17.78 CP*	*24.4*	*20.3*
				NOTES: Four-element full-bridge pattern for shear-strain measurement. Grids are spaced 90° apart, and 45° from pattern centerlines. Exposed solder tab area is 0.16 x 0.10 in *(4.1 x 2.5 mm).*					
250UT 	CEA-XX-250UT-120	A	120 ±0.4%	0.250 ES	0.450 CP	0.290 ES	0.650 CP	0.55	0.74
	CEA-XX-250UT-350	B	350 ±0.4%	*6.35 ES*	*11.43 CP*	*7.37 ES*	*16.51 CP*	*14.0*	*18.8*
				NOTES: General-purpose two-element 90° 'tee' rosette. Exposed solder tab area is 0.13 x 0.10 in *(3.3 x 2.5 mm).*					
250UN 	CEA-XX-250UN-120	$\boxed{A}$	120 ±0.3%	0.250	0.415	0.120	0.120	0.52	0.20
	CEA-XX-250UN-350	$\boxed{A}$	350 ±0.3%	*6.35*	*10.54*	*3.05*	*3.05*	*13.2*	*5.1*
				NOTES: General-purpose gage with narrow geometry. Exposed solder tab area is 0.08 x 0.05 in *(2.0 x 1.1 mm).*					
250UW 	CEA-XX-250UW-120	$\boxed{A}$	120 ±0.3%	0.250	0.450	0.180	0.180	0.55	0.27
	CEA-XX-250UW-175	C	175 ±0.3%	*6.35*	*11.43*	*4.57*	*4.57*	*14.0*	*6.9*
	CEA-XX-250UW-350	$\boxed{A}$	350 ±0.3%	**NOTES:** General-purpose 1/4-in *(6.4-mm)* gage. Exposed solder tab area is 0.10 x 0.07 in *(2.5 x 1.8 mm).*					
	CEA-XX-250UW-10C	C	1000 ±0.3%						
375UW 	CEA-XX-375UW-120	B	120 ±0.3%	0.375	0.575	0.180	0.180	0.67	0.27
	CEA-XX-375UW-350	B	350 ±0.3%	*9.53*	*14.61*	*4.57*	*4.57*	*17.0*	*6.9*
				NOTES: General-purpose 3/8-in *(9.5-mm)* gage. Exposed solder tab area is 0.10 x 0.07 in *(2.5 x 1.8 mm).*					
500UW 	CEA-XX-500UW-120	A	120 ±0.3%	0.500	0.700	0.180	0.180	0.80	0.27
	CEA-XX-500UW-350	A	350 ±0.3%	*12.70*	*17.78*	*4.57*	*4.57*	*20.3*	*6.9*
				NOTES: General-purpose 1/2-in *(12.7-mm)* gage. Exposed solder tab area is 0.10 × 0.07 in *(2.5 x 1.8 mm).*					

† S... ordering information [illegible]

‡ ... dimensions [illegible] ... include ... pattern and do not include [illegible] ... backing.

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Printed in USA

APF.

PSI-TRONIX
4509 RUNWAY ST.
SIMI VALLEY,CA
93063

FINAL TEST REPORT

MODEL PSI-5000
SERIAL NO 4986

CUSTOMER
CUSTOMER PO#
DATE 03/07/88

PRESS PSIG	INCR. (V)	DECR. (V)	S/L (V)	LIN. %FS	HYST. %FS
0	.06652	.06556	.06652		-.019
1000	1.06704	1.06576	1.07179	-.095	-.025
2000	2.07160	2.07060	2.07707	-.109	-.020
3000	3.07860	3.07770	3.08235	-.075	-.018
4000	4.08460	4.08540	4.08762	-.060	.016
5000	5.09290		5.09290		

TEMP DEG. F	TEMP DEG. F	TEMP DEG. F
0	78	+130
.08003	.06652	.04328
5.05480	5.09290	5.12290

TESTED BY________________________

227

PSI-TRONIX
4509 RUNWAY ST.
SIMI VALLEY,CA
93063

FINAL TEST REPORT

MODEL PSI-5000
SERIAL NO 5817

CUSTOMER
CUSTOMER PO#
DATE 03/07/88

PRESS PSIG	INCR. (V)	DECR. (V)	S/L (V)	LIN. %FS	HYST. %FS
0	.06134	.05994	.06134		-.028
1000	1.05853	1.05679	1.06745	-.177	-.035
2000	2.06240	2.06050	2.07356	-.[illegible]2	-.038
3000	3.07010	3.06910	3.07968	-.190	-.020
4000	4.07940	4.08040	4.08579	-.127	.020
5000	5.09190		5.09190		

TEMP DEG. F	TEMP DEG. F	TEMP DEG. F
0	78	+130
.09911	.06134	.00855
5.04950	5.09190	5.07820

TESTED BY ______________________

[illegible]

PSI-TRONIX
4509 RUNWAY ST.
SIMI VALLEY,CA
93063

FINAL TEST REPORT

MODEL PSI-5000
SERIAL NO 5815

CUSTOMER
CUSTOMER PO#
DATE 03/07/88

PRESS PSIG	INCR. (V)	DECR. (V)	S/L (V)	LIN. %FS	HYST. %FS
0	.06904	.06890	.06904		-.003
1000	1.06596	1.06561	1.07360	-.152	-.007
2000	2.06920	2.06900	2.07815	-.178	-.004
3000	3.07530	3.07630	3.08270	-.147	.020
4000	4.08290	4.08420	4.08725	-.087	.026
5000	5.09180		5.09180		

TEMP DEG. F 0	TEMP DEG. F 78	TEMP DEG. F +130
.06963	.06904	.07690
5.02140	5.09180	5.16720

TESTED BY__________________________

[illegible]

PSI-TRONIX
4509 RUNWAY ST.
SIMI VALLEY,CA
93063

FINAL TEST REPORT

MODEL PSI-5000
SERIAL NO 5723

CUSTOMER
CUSTOMER PO#
DATE 03/07/88

PRESS PSIG	INCR. (V)	DECR. (V)	S/L (V)	LIN. %FS	HYST. %FS
0	.07593	.07616	.07593		.005
1000	1.07198	1.07335	1.07821	-.124	.027
2000	2.07320	2.07500	2.08048	-.145	.036
3000	3.07660	3.07910	3.08275	-.123	.050
4000	4.08150	4.08400	4.08503	-.070	.050
5000	5.08730		5.08730		

TEMP DEG. F 0	TEMP DEG. F 78	TEMP DEG. F +130
.04404	.07593	.09227
5.01180	5.08730	5.15420

TESTED BY ____________________

A-PF3

PSI-TRONIX
4509 RUNWAY ST.
SIMI VALLEY,CA
93063

FINAL TEST REPORT

MODEL PSI-5000
SERIAL NO 5885

CUSTOMER
CUSTOMER PO#
DATE 03/07/88

PRESS PSIG	INCR. (V)	DECR. (V)	S/L (V)	LIN. %FS	HYST. %FS
0	.06735	.06449	.06735		-.057
1000	1.06413	1.06219	1.07344	-.185	-.039
2000	2.06850	2.06710	2.07953	-.219	-.028
3000	3.07710	3.07710	3.08562	-.169	0.000
4000	4.08830	4.08780	4.09171	-.068	-.010
5000	5.09780		5.09780		

TEMP DEG. F 0	TEMP DEG. F 78	TEMP DEG. F +130
.10837	.06735	.04922
5.08270	5.09780	5.13010

TESTED BY________________________

AF33

PSI-TRONIX
4509 RUNWAY ST.
SIMI VALLEY,CA
93063

FINAL TEST REPORT

MODEL PSI-5000
SERIAL NO 5883

CUSTOMER
CUSTOMER PO#
DATE 03/07/88

PRESS PSIG	INCR. (V)	DECR. (V)	S/L (V)	LIN. %FS	HYST. %FS
0	.06860	.06861	.06860		.000
1000	1.06427	1.06597	1.07304	-.175	.034
2000	2.06670	2.06930	2.07748	-.215	.052
3000	3.07280	3.07640	3.08192	-.182	.072
4000	4.08170	4.08420	4.08636	-.093	.050
5000	5.09080		5.09080		

TEMP DEG. F	TEMP DEG. F	TEMP DEG. F
0	78	+130
.10505	.06860	.05625
5.07110	5.09080	5.13450

TESTED BY__________________________

BP1

PSI-TRONIX
4509 RUNWAY ST.
SIMI VALLEY,CA
93063

FINAL TEST REPORT

MODEL PSI-5000
SERIAL NO 5892

CUSTOMER DYCOR INDUSTRIAL
CUSTOMER PO# 41180
DATE 03/11/88

PRESS PSIG	INCR. (V)	DECR. (V)	S/L (V)	LIN. %FS	HYST. %FS
0	.07241	.06895	.07241		-.069
2000	1.06259	1.05537	1.07649	-.277	-.144
4000	2.06600	2.05730	2.08057	-.290	-.173
6000	3.07630	3.06730	3.08464	-.166	-.179
8000	4.08750	4.08050	4.08872	-.024	-.139
10000	5.09280		5.09280		

TEMP DEG. F 0	TEMP DEG. F 78	TEMP DEG. F +130
.08121	.07241	.08556
5.08100	5.09280	5.10940

TESTED BY______________________

BP1

BP2

PSI-TRONIX
4509 RUNWAY ST.
SIMI VALLEY,CA
93063

FINAL TEST REPORT

MODEL PSI-5000
SERIAL NO 5773

CUSTOMER DYCOR INDUSTRIAL
CUSTOMER PO# 41180
DATE 03/11/88

PRESS PSIG	INCR. (V)	DECR. (V)	S/L (V)	LIN. %FS	HYST. %FS
0	.06842	.06728	.06842		-.023
2000	1.06254	1.05964	1.07408	-.229	-.058
4000	2.06890	2.06520	2.07973	-.215	-.074
6000	3.08070	3.07650	3.08539	-.093	-.084
8000	4.09170	4.08900	4.09104	.013	-.054
10000	5.09670		5.09670		

TEMP DEG. F	TEMP DEG. F	TEMP DEG. F
0	78	+130
.08278	.06842	.06244
5.07110	5.09670	5.11560

TESTED BY________________________

BP2

BP3

PSI-TRONIX
4509 RUNWAY ST.
SIMI VALLEY,CA
93063

FINAL TEST REPORT

MODEL PSI-5000
SERIAL NO 5889

CUSTOMER DYCOR INDUSTRIAL
CUSTOMER PO# 41180
DATE 03/11/88

PRESS PSIG	INCR. (V)	DECR. (V)	S/L (V)	LIN. %FS	HYST. %FS
0	.06390	.06249	.06390		-.028
2000	1.05775	1.05330	1.06820	-.208	-.089
4000	2.06250	2.05700	2.07250	-.199	-.110
6000	3.07230	3.06700	3.07680	-.090	-.106
8000	4.08060	4.07750	4.08110	-.010	-.062
10000	5.08540		5.08540		

TEMP DEG. F 0	TEMP DEG. F 78	TEMP DEG. F +130
.09461	.06390	.04184
5.10340	5.08540	5.07160

TESTED BY________________________

BP3

BP4

PSI-TRONIX
4509 RUNWAY ST.
SIMI VALLEY,CA
93063

FINAL TEST REPORT

MODEL PSI-5000
SERIAL NO 5887

CUSTOMER DYCOR INDUSTRIAL
CUSTOMER PO# 41180
DATE 03/11/88

PRESS PSIG	INCR. (V)	DECR. (V)	S/L (V)	LIN. %FS	HYST. %FS
0	.06385	.06002	.06385		-.076
2000	1.05847	1.04993	1.06976	-.224	-.170
4000	2.06380	2.05500	2.07567	-.236	-.175
6000	3.07610	3.06640	3.08158	-.109	-.193
8000	4.08710	4.08090	4.08749	-.008	-.123
10000	5.09340		5.09340		

TEMP DEG. F 0	TEMP DEG. F 78	TEMP DEG. F +130
.04419	.06385	.06040
5.05710	5.09340	5.10090

TESTED BY________________________

BP4

BP5

PSI-TRONIX
4509 RUNWAY ST.
SIMI VALLEY.CA
93063

FINAL TEST REPORT

MODEL PSI-5000
SERIAL NO 5891

CUSTOMER DYCOR INDUSTRIAL
CUSTOMER PO# 41180
DATE 03/11/88

PRESS PSIG	INCR. (V)	DECR. (V)	S/L (V)	LIN. %FS	HYST. %FS
0	.06401	.06134	.06401		-.053
2000	1.05588	1.05048	1.06929	-.267	-.107
4000	2.06100	2.05460	2.07457	-.270	-.127
6000	3.07280	3.06500	3.07985	-.140	-.155
8000	4.08360	4.07850	4.08512	-.030	-.101
10000	5.09040		5.09040		

TEMP DEG. F	TEMP DEG. F	TEMP DEG. F
0	78	+130
.07196	.06401	.03051
5.08030	5.09040	5.06820

TESTED BY________________________

BP5

Volume

2

TP 9668E

FULL-SCALE TESTS ON THE RESPONSE OF ICE STRENGTHENED PROPELLER BLADES TO ICE LOADS

Volume II: Data Analysis Report

Prepared for

Transportation Development Centre
Policy and Coordination Group
Transport Canada

by

GEOTECHnical Resources Ltd.

March 1989

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TP9668E

FULL SCALE TESTS ON THE RESPONSE OF ICE STRENGTHENED PROPELLER BLADE TO ICE LOADS

VOLUME II: DATA ANALYSIS REPORT

by:

Vlodek Laskow
Arctic Research and Development

for

GEOTECHnical resources ltd.

March, 1989

427215

DDN 425545

DISCLAIMER: The contents of this report reflect the views of the authors and not necessarily the official view or opinions of the Transportation Development Centre of Transport Canada.

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Vlodek Laskow

Transport Canada Transports Canada

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16. Abstract

Propellers on ice-going vessels break due to ice forces. A propeller test program consisted of loading a 2600 kg Cunial bronze blade from the Canmar Kigoriak. It was mounted on a reaction frame and three servo-controlled hydraulic actuators forced a 1.3 m diameter by 0.75 m thick block of fresh water ice onto the blade at speeds from 3 mm/s to 100 mm/s. The applied load (3 locations) blade strain (14 locations), blade deformation (3 locations) and local interaction pressure (5 locations) were recorded. The blade was loaded normal to it's surface until permanent deformation occurred. A load of 1 MN applied near the blade tip produced minor plastic deformation near the blade tip. The ultimate blade load capacity according to the manufacturer was 1.8 MN. Tests at 100 mm/s created a brittle ice failure mode, tests at 3 mm/s produced ductile ice failure. The largest loads occurred during the slow tests. Two tests used wood instead of ice, the results were similar to the slow speed ice tests. The engineering significance of the tests is that blade stiffness as well as blade strength are both important. The current blade regulations do not incorporate the results of this study.

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16. Résumé

Les hélices des cargos brise-glace cèdent parfois aux sollicitations exercées par les glaces. Des essais de choc ont été menés sur une pale d'hélice en bronze Cu-Ni-Al pesant 2 600 kg, prélevée sur l'hélice du Canmar-Kigoriak. Les essais ont eu lieu sur un bâti construit exprès, comportant un actionneur hydraulique asservi, à trois têtes, qui a permis d'appuyer un bloc de glace d'eau douce de 1,3 m de diamètre sur 0,75 m d'épaisseur sur l'intrados de la pale, à des vitesses comprises entre 3 et 100 mm/s. Les efforts dynamométriques (3 endroits), les contraintes (14 endroits), les déformations (3 endroits) et les pressions localisées (5 endroits) ont été mesurés et enregistrés. La charge a été appliquée normalement à la surface de la pale au point de provoquer une déformation permanente. Une charge de 1 MN près du bout de la pale y a provoqué une légère déformation plastique. Selon les fabricants, la charge maximale que peut supporter la pale est de 1,8 MN. Les essais de choc à des vitesses de 100 et de 3 mm/s ont provoqué la rupture fragile et celle ductile de la glace. Les charges les plus élevées ont été observées aux vitesses les plus basses. Deux essais utilisant du bois plutôt que de la glace ont donné des résultats analogues aux essais avec la glace aux vitesses faibles. Pour l'ingénieur, les résultats montrent l'importance qu'il faut donner à la raideur de la pale aussi bien qu'à sa résistance. La réglementation en vigueur se rapportant aux pales d'hélice ne tient pas compte des résultats de la présente étude.

17. Mots clés
Hélice, résistance, charges glacielles.

18. Diffusion
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SUMMARY

Regulatory bodies, ship designers and ship operators are all concerned with a variety of damage to vessels. There are many situations where damage can occur to propellers. A particularly severe case is the following. In order to reverse the direction of motion of a vessel with a fixed pitch propeller the rotation of the propeller shafting has to be reversed. During this reversal, a critical period occurs in which the shaft is stopped but the vessel may still be moving. If the ship or, more significantly, the blade contacts a massive piece of ice, the blade may break.

In this project we took an ice-strengthened bronze propeller blade from the Canmar Kigoriak and instrumented it for testing. A non-destructive series of tests on the blade revealed a crack system in the root of the blade. Subsequently, the blade was rammed into hard fresh water ice and the forces, pressures and reactions were measured. Some tests were conducted when the blade was permanently deformed.

A steel reaction frame and blade tie-down assembly was designed and constructed. It was designed to withstand approximately 2.5 MN applied to the blade tip, at the relative radius 0.9 and 0.5 m off from the centre line. A triple high speed actuator assembly pushed a containment vessel full of ice into the blade surface. Speeds between 3 and 100 mm/s were achieved which directly simulate the situation of the fixed pitch propeller hitting a massive ice feature. The applied loading and block reaction were monitored by a series of installed transducer systems and recorded via a digital data acquisition system.

The loads from each actuator were determined by recording the hydraulic oil pressure. Strain gauges were placed at strategic locations on the blade surface and recorded blade strains. While the blade material is still elastic, these data can provide measures of the blade stress. As one of the aims of the project was to produce permanent deflection in the blade, these gauges were also used to determine load levels at which the blade went plastic. The set of displacement gauges recorded the out of plane blade deflection, both elastic and plastic. A set of sensors recorded the ice/blade interaction pressures within the interaction zone.

In order to permanently deform the blade, the tests indicated that the displacement available from the actuators was the limiting factor rather than available load capacity. For this reason, wood was used instead of ice as the impact medium for two tests. Additionally, two hammer tests were conducted which recorded the free vibration modes of the propeller blade. The test results are summarized in Table 1.

TABLE 1

SUMMARY OF ICE IMPACT TESTS

TEST No.	ICE TYPE	ICE COND'N	CONTACT SHAPE ICEFOOT	SURFACE AREA m^2	SPEED mm/s	MAX. LOAD MN	LOCATION	COMMENTS	STRAINS
1	Blocks	New	Rectang.	1.00	91.5	0.66	Center	2 Load Peaks	Elastic
2	Crushed	New	Circular	1.54	85.7	0.53	Center		Elastic
3	Crushed	Used	Circular	1.20	83.3	0.53	Center		Elastic
4	Crushed	Used	Polygon	0.68	100.0	1.03	Center	2 Load Peaks	Elastic
5	Crushed	New	Triang	0.60	100.0	0.37	Center	2 Load Peaks	Elastic
6	Crushed	Used	Polygon	0.10	101.5	0.57	Center		Elastic
7	Crushed	New	Circular	0.38	102.7	0.37	L. Edge	2 Load Peaks	Elastic
8	Crushed	New	Circular	0.68	100.0	0.53	L. Edge	2 Load Peaks	Elastic
9	Crushed	New	Circular	1.25	100.7	1.28	L. Edge	2 Load Peaks	Plastic
10	Crushed	Used	Circular	0.91	102.9	0.42	L. Edge		Elastic
11	Crushed	Used	Circ/Res	0.91	100.7	1.13	L. Edge	2 Load Peaks	Elastic
12	Crushed	New	Circular	1.25	100.7	1.27	L. Edge		Elastic
13	Aborted								Elastic
14	Crushed	New	Circular	1.25	3.0	1.75	L. Edge	Ductile	Plastic
15	Crushed	Used	Polygon	0.60	5.5	3.93	L. Edge	Ductile	Plastic
16	Free Vibration Test						T. Edge		Elastic
17	Free Vibration Test						Center		Elastic
18	Timber	New		0.30	103.5	2.05	L. Edge		Plastic
19	Timber	Used		0.30	102.7	2.40	Bucket	Collapsed	Plastic

The vast amount of data collected in the experiment was inspected and the dominant characteristics were extracted:

1. The center part of the blade attracts more load than the edge; hence, the point of application of the load gravitates towards the centerline of the blade.

2. The point of application of the loads corresponds closely to the ones observed in full scale tests.

3. The maximum load pressures recorded during these tests was 28.20 MPa during test PBT15.

4. Two types of pressure build-up are identified - ductile and brittle

5. The maximum load recorded was in the same test that produced the maximum local pressures (Test PBT15).

6. At the leading edge, blade displacements of about 57 mm are needed to cause plastic deformations.

7. For the ductile type of tests, 71% of the input energy went into the blade.

8. For brittle type of tests, most of the input energy went into the ice crushing and extraction.

9. At an applied load of about 1 MN, all load/strain curves start deviating from the linear relationship.

10. At the stress level of 200 MPa, plastic flow of the material was registered.

The various observations on the interaction and on the response of the blade to the loading was critically reviewed in terms of the engineering significance of the tests. These important conclusions are summarized below.

1. The blade of the shrouded CPP propeller was found to be very strong in terms of the ultimate load it was able to carry with complete destruction 3.95 MN. This is more than twice the 1.838 MN stated as a blade collapsing load by the propeller manufacturer.

2. At that load level, the blade residual deformation near the leading edge was significant (40 mm), but localized and the blade was considered to be still operational perhaps at reduced RPM.

3. Although a number of high loads were applied, there was no evidence of brittle behaviour. This means that the existing crack near the blade root was probably caused by cyclic loading of low amplitude for example hydrodynamic or inertial loads and not by the individual high loads coming from direct contact with the ice. The crack is located on the compression side.

4. The issue of blade suitability for service is not based on the ultimate load it can carry, but on the geometry of the deformed blade and its influence on blade performance and vibration levels in that condition. Therefore, this is an issue of the stiffness of the blade sections, rather than their strength.

5. More than half of the strain energy of the blade goes into the plastic deformation. This shows that the plasticity of the blade is a blade protection mechanism and should be considered in modelling of the blade response to high loads.

6. The existing models of ice/propeller blade interactions do not reflect the results of the test performed. New developments are needed in this field.

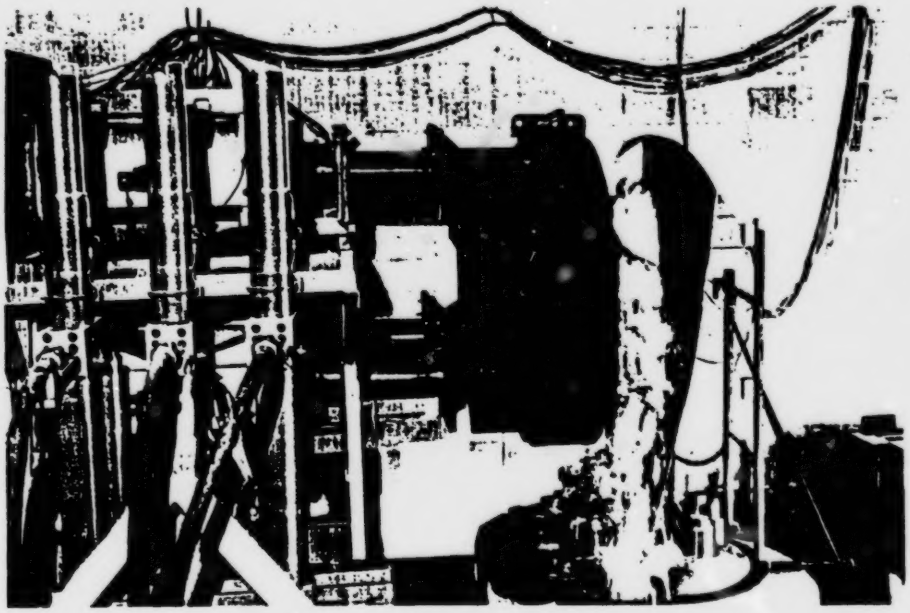
We recommend that:

1. A model of ice/blade interaction be developed and implemented, reflecting the wealth of new information collected.

2. A comparison of test data with field data be carried out for the purpose of explaining the cause of propeller damages.

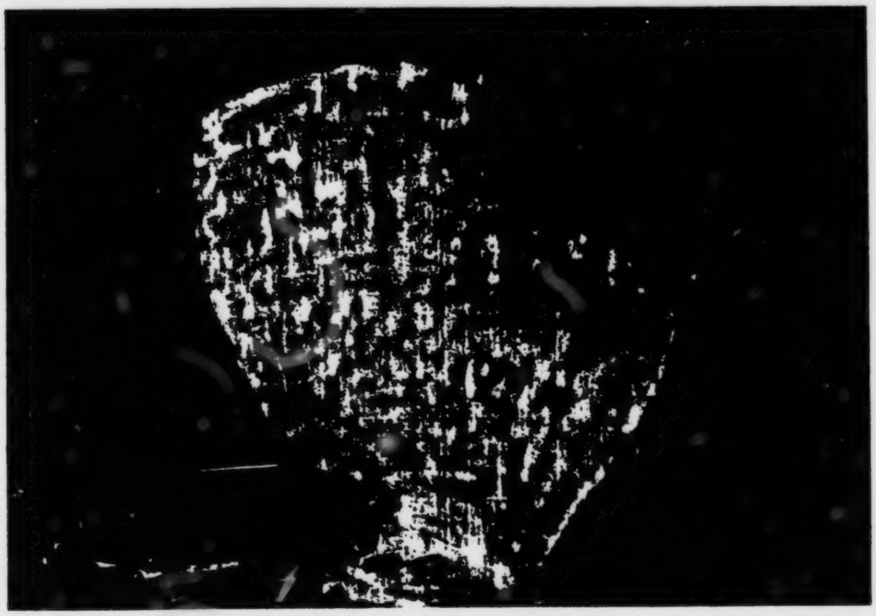
3. A material-oriented experimental study be carried out to determine the plastic, ultimate and fatigue properties of various propeller blade materials in order to establish the causes of the existing blade failures.

4. An analysis of the test data with respect to their application to Arctic Shipping Pollution Prevention Regulations, the strength/stiffness issue, blade be carried out.



Experimental Set-Up

Dispositif Experiment



Propeller Blade

Helice

SOMMAIRE

L'endommagement des navires est un sujet qui préoccupe beaucoup tous les corps intéressés: architectes navals, armateurs et instances réglementaires, et en particulier l'endommagement des hélices qui peut survenir dans un grand nombre de cas. Le cas le plus préoccupant est celui du navire équipé d'une hélice à pas fixe; lorsqu'il fait marche arrière, le sens de rotation de l'arbre porte-hélice est inversé. Durant ce processus, arrive un moment critique où l'arbre cesse sa rotation, mais où le navire peut continuer sa marche. Ainsi, si ce dernier, ou plus dangereusement encore, une pale de l'hélice heurte un gros fragment de glace, elle risque de se briser.

La recherche effectuée a consisté à prélever une pale de l'hélice en bronze renforcée, équipant le Canmar-Kigoriak, et à l'instrumenter en vue des chocs à lui faire subir. La série d'essais non destructifs effectués sur la pale a mis en évidence une fissure au pied de la pale. Par la suite, la pale a été projetée contre un bloc de glace d'eau douce, pendant que la chaîne de mesure enregistrait les forces, pressions et réactions en jeu. Certains essais ont été menés après que la pale eut connu une déformation permanente.

Aux fins de la recherche, un bâti de réaction complété d'un dispositif pour maintenir la pale d'hélice en place a été construit, concu afin de résister à des forces de quelque 2,5 MN appliquées en bout de pale à une distance allant de 0,5 à 0,9 m, par rapport à l'axe central. Un actionneur à trois têtes, avançant à une vitesse relativement élevée, a appuyé un récipient contenant de la glace contre l'intrados de la pale. Les vitesses d'avance pratiquées entre 3 et 100 mm/s reproduisent celles d'une hélice à pas fixe lorsqu'elle heurte un gros fragment de glace. Tant les charges appliquées que les réactions du bâti ont été captées, grâce à un réseau de transducteurs, et transmises à une chaîne de mesure numérique qui les a enregistrées.

La charge appliquée par chacune des têtes de l'actionneur a été déterminée par le mesurage de la pression hydraulique exercée sur elles. Judicieusement placées sur l'intrados de la pale, des jauges extensométriques ont capté les déformations subies, qui sont proportionnelles aux contraintes exercées, tant que le matériau n'a pas subi de déformation plastique. Toutefois, comme l'un des objectifs de la recherche avait été de pousser l'essai au point de provoquer la déformation permanente de la pale, ces mêmes jauges ont servi à déterminer les pressions auxquelles s'amorce ce type de déformation. Le réseau de capteurs de déplacement a permis d'enregistrer les déformations, tant élastiques que plastiques, hors du plan de la pale. Un troisième réseau de capteurs dynamométriques a permis de mesurer les pressions d'interaction glace-pale à l'intérieur de la zone touchée. Les essais ont montré que, pour provoquer la déformation permanente de la pale, le facteur contraignant était moins la capacité de charge que l'amplitude du déplacement apporté par l'actionneur. Pour cette raison, du bois a été utilisé plutôt que de la glace dans deux des trois essais de choc. Enfin, deux essais de choc au marteau ont été faits en vue de déterminer les modes de vibration à l'état libre de la pale. Le tableau 1 donne les résultats obtenus des essais décrits.

TABLEAU 1

Résultats des essais de choc contre la glace

Essai no.	Glace		Form de la glace au contact	Surface (m2)	Vitesse (mm/s)	Charge max. (MN)	Point de contact	Observations	Déformation
	Type	Etat							
1	Bloc	Neuve	Rectang.	1.00	91.5	0.66	central	Deux pics de charge	élastique
2	Concassée	Neuve	Circulaire	1.54	85.7	0.53	central		élastique
3	Concassée	Usagée	Circulaire	1.20	83.3	0.53	central		élastique
4	Concassée	Usagée	Polygonale	0.68	100.0	1.03	central	Deux pics de charge	élastique
5	Concassée	Neuve	Triangulaire	0.60	100.0	0.37	central	Deux pics de charge	élastique
6	Concassée	Usagée	Polygonale	0.10	101.5	0.57	central		élastique
7	Concassée	Neuve	Circulaire	0.38	102.7	0.37	bord d'attaque	Deux pics de charge	élastique
8	Concassée	Neuve	Circulaire	0.68	100.0	0.53	bord d'attaque	Deux pics de charge	élastique
9	Concassée	Neuve	Circulaire	1.25	100.7	1.28	bord d'attaque	Deux pics de charge	plastique
10	Concassée	Usagée	Circulaire	0.91	102.9	0.42	bord d'attaque		élastique
11	Concassée	Usagée	Circulaire	0.91	100.7	1.13	bord d'attaque	Deux pics de charge	élastique
12	Concassée	Neuve	Circulaire	1.25	100.7	1.27	bord d'attaque		élastique
13	interrompu								
14	Concassée	Neuve	Circulaire	1.25	3.0	1.75	bord d'attaque	Ductile	plastique
15	Concassée	Usagée	Polygonale	0.60	5.5	3.93	bord d'attaque	Ductile	plastique
16	Essai vibratoire à l'état libre						bord de fuite		élastique
17	Essai vibratoire à l'état libre						central		élastique
18	Bois	Neuf		0.30	103.5	2.05	bord d'attaque		plastique
19	Bois	Usagé		0.30	102.7	2.40	récipient	Ruine	plastique

L'énorme quantité de données, une fois dépouillée, a révélé les détails intéressants suivants:

1. La partie centrale de la pale est plus chargée que ses bords. Il s'ensuit que les points de charge gravitent autour de l'axe longitudinal de la pale.

2. Les points de charge correspondent de près à ceux observés lors des essais en vraie grandeur.

3. La pression la plus forte observée a été de 28,20 MPa pour l'essai PBT15.

4. Les zones de tension observées sont de deux types: ductile et fragile.

5. L'essai PBT15 qui a produit la pression la plus forte a également produit la charge la plus élevée.

6. Il faut un déplacement de quelque 57 mm sur le bord d'attaque de la pale pour provoquer une déformation plastique.

7. Dans les essais de ductilité, 71 p. 100 de l'énergie mise en oeuvre a été consommée par la pale.

8. Lors des essais de fragilité, presque toute l'énergie mise en oeuvre a été consommée par l'écrasement de la glace et son extraction.

9. A partir d'une charge d'environ 1 MN, toutes les courbes contrainte-déformation cessent d'être linéaires.

10. Un écoulement plastique a été observé à la pression de 200 MPa.

Toutes les observations faites sur les interactions ainsi que la réponse de la pale aux sollicitations ont été revues et interprétées du point de vue de l'ingénieur. Cela a donné les constatations suivantes:

1. La pale de l'hélice à pas variable, protégée par une tuyère, s'est révélée être très robuste quant à la charge maximale qu'elle peut supporter jusqu'à la ruine totale, 3,95 MN, soit plus du double du 1,838 MN donné par les fabricants eux-mêmes.

2. A cette valeur de charge, la déformation résiduelle de la pale près du bord d'attaque a été considérable (40 mm) bien que localisée, et la pale reste quand même fonctionnelle, à condition de réduire le régime.

3. Malgré le nombre de cycles de charge, et leur amplitude élevée, aucune tendance à la fragilité n'a été observée. Ce qui veut dire que la fissure constatée au pied de la pale est probablement due à des cycles de charge de faible amplitude, des charges hydrodynamiques ou inertielles, par exemple, et non causée par les cycles de forte amplitude attribuables au contact direct avec la glace. La fissure se trouve du côté intrados de la pale.

4. La fonctionnalité de la pale ne dépend pas de sa robustesse (charge de rupture) mais bien de sa géométrie déformée sous charge et de l'influence que celle-ci a sur le rendement propulsif de l'hélice et les niveaux vibratoires. Le problème doit donc être envisagé sous l'angle de la raideur des sections de pale et non de leur résistance.

5. Plus de la moitié de l'énergie dépensée pour solliciter la pale est consommée par le processus de déformation plastique. Ce qui montre que la déformabilité plastique de la pale constitue un mécanisme de protection et qu'il devrait donc entrer en ligne de compte dans la modélisation de la réponse d'une pale aux charges élevées.

Recommandations:

1. Elaborer et utiliser un modèle de simulation des interactions glaces-pale d'hélice qui tienne compte des résultats obtenus.

2. Entreprendre la comparaison des données théoriques aux données pratiques, dans le but de mettre en évidence la cause des avaries aux hélices.

3. Lancer une étude et des expérimentations sur les divers matériaux entrant dans la fabrication des hélices en vue de déterminer les charges correspondant à la limite d'élasticité, à la charge maximale et à la rupture par fatigue et, ainsi, mettre en évidence les causes de la ruine des pales d'hélice.

4. Analyser les données sous le rapport de leur utilisation dans la réglementation d'application de la Loi sur la prévention de la pollution dans l'Arctique se rapportant à la question du rapport résistance/raideur de la pale d'hélice et aux critères de résistance à respecter.

TABLE OF CONTENTS

1.0 INTRODUCTION 1.1

2.0 OBJECTIVES OF DATA ANALYSIS 1.1

3.0 PROPERTIES OF THE BLADE 3.1

- 3.1 Principal Characteristics 3.1
- 3.2 Natural Vibration Frequencies in Air 3.3

4.0 TESTS SUMMARY 4.1

- 4.1 Tests Setup 4.1
- 4.2 Tests Execution 4.2
- 4.3 Test Results 4.2
- 4.4 Description of the Individual Tests 4.3
- 4.5 Miscellaneous Comments on the Tests 4.8

5.0 DATA ANALYSIS 5.1

- 5.1 General Observations Regarding the Ice/Blade Interaction Process 5.1
- 5.2 Calculations of the Effective Location of Load Application 5.2
- 5.3 Analysis of Pressure Distribution in the Interaction Zone 5.3
- 5.4 Comparison of the Applied Load with the Blade Strains, Stresses and Displacements 5.4
- 5.5 Identification of Loads Causing Plastic Deformation 5.5
- 5.6 Quantification of the Energy Aspects of the Blade Response 5.6

6.0 ENGINEERING SIGNIFICANCE OF THE TEST RESULTS 6.1

7.0 CONCLUSIONS AND RECOMMENDATIONS 7.1.1

- 7.1 Conclusions 7.1.1
- 7.2 Recommendations 7.2.1

8.0 REFERENCES 8.1

APPENDICES

APPENDIX A: GEOMETRY OF THE BLADE A.1

APPENDIX B: TEST LOGS B.1

LIST OF FIGURES

CHAPTER 3: PROPERTIES OF THE BLADE

Figure 3.1 Blade Geometry 3.5
Figure 3.2 Pitch Angle Distribution Along The Blade 3.6
Figure 3.3 Maximum Thickness Distribution Along the Blade 3.7
Figure 3.4 Geometric Properties of the Blade as a Function of Blade Radius 3.9
Figure 3.5 Location of Impact Points for Vibration Tests 3.11
Figure 3.6 Record of Vibrations for Test #16 3.12
Figure 3.7 Recrod of Vibrations for Test #17 3.13
Figure 3.8 Onset of Yield for Cunial 3.14
Figure 3.9 Strain-Stress Curve for Cunial 3.15
Figure 3.10 Simplified Strain/Stress Curve for Cunial 3.16

CHAPTER 4: TESTS SUMMARY

Figure 4.1 Apparatus for Kigoriak Blade Tests 4.9
Figure 4.2a Compression Side Instrumentation 4.10
Figure 4.2b Tension Side Instrumentation 4.11
Figure 4.3 Ice Contact Geometry During the Tests 4.16
Figure 4.4 Total Load and Actuator Displacement as a Function of Time, Test #15 4.17

CHAPTER 5: DATA ANALYSIS

Figure 5.1.1 Comparison Between Brittle and Ductile Ice/Blade Interactions 5.1.5
Figure 5.1.2 Post Failure Load as a Function of Ice Failure Load 5.1.7
Figure 5.1.3 Speed of Loading Versus Speed of Advance 5.1.8
Figure 5.1.4 Blade Single-Axis Strain Graphs for BS4 & BS5 5.1.9

Figure 5.2.1 Geometry of the Actuators 5.2.5
Figure 5.2.2. Loci of the Total Force Within the Triangle, Tests 1 - 6 5.2.7
Figure 5.2.3 Loci of the Total Force Within the Triangle, Tests 7 - 19 5.2.8
Figure 5.2.4 Location of the Total Load as a Function of Load Magnitude 5.2.9
Figure 5.2.5 Locations of Center of Loads Within the Actuators Triangle 5.2.10
Figure 5.2.6 Location of the Center of Effort on the Blade 5.2.11
Figure 5.2.7 Change of the Center of Effort as a Function of Load 5.2.12
Figure 5.2.8 Load as a Function of Time, Test #15 5.2.13
Figure 5.2.9 Plots of One Actuator Versus the Other, Test 1 5.2.14

Figure 5.3.1 Arrangement of the Pressure Gauges on the Pressure Side of the Blade 5.3.8
Figure 5.3.2a Arrangement of the Pressure Gauges on the Pressure Side of the Blade 5.3.9
Figure 5.3.2b Arrangement of the Pressure Gauges on the Pressure Side of the Blade 5.3.10
Figure 5.3.3 Trace of Maximum Blade Surface Pressure, Test 15 5.3.12
Figure 5.3.4 Peak Pressure/Area Relationship from all Tests 5.3.13
Figure 5.3.5 Local Pressure Variations Versus Average Pressure 5.3.15
Figure 5.3.6 Average and Maximum Pressures as a Function of Maximum Load/Creep Tests 5.3.16
Figure 5.3.7 Peak Pressures as a Function of the Load at the Time 5.3.17
Figure 5.3.8 Average Pressure on the Pickup as a Function of Total Load 5.3.18
Figure 5.3.9 Peak Blade and Average Pickup Pressures as a Function of Bucket Maximum Pressure 5.3.19
Figure 5.3.10 Average of Maximum Pickup Pressure as a Function of Apparent Pressure 5.3.20
Figure 5.3.11 Maximum of Maximum Pickup Pressures as a Function of Apparent Pressure 5.3.21
Figure 5.3.12 Maximum Bucket Pressure as a Function of Apparent Pressure 5.3.22
Figure 5.3.13 Average of the Maximum Pickup Pressure as a Function of Apparent Pressure 5.3.23
Figure 5.3.14 Maximum of Maximum Pickup Pressures as a Function of Apparent Pressure 5.3.24
Figure 5.3.15 Maximum Bucket Pressure as a Function of Apparent Pressure 5.3.25
Figure 5.3.16 Duration of Peak Pressure as a Function of its Magnitude 5.3.26
Figure 5.3.17 Traces of Blade Surface Pressure Signals for BP1/BP2 5.3.27
Figure 5.3.18 Traces of Blade Surface Pressure Signals for BP3/BP4 5.3.28
Figure 5.3.19 Traces of Blade Surface Pressure Signals for BP5 5.3.29
Figure 5.3.20 Correlation of the Pressure at PB3 Versus Total Load Developed 5.3.30
Figure 5.3.21 Pressure Gauge Readings; Test #1 5.3.31
Figure 5.3.22 Pressure Gauge Readings; Test #9 5.3.32
Figure 5.3.23 Pressure Gauge Readings; Test #12 5.3.33
Figure 5.3.24 Pressure Gauge Readings; Test #15 5.3.34

Figure 5.4.1 Maximum Load on the Blade as Function of Distance Travelled 5.4.9
Figure 5.4.2 Maximum Displacement of the Blade as a Function of Maximum Load for BD1 5.4.10
Figure 5.4.3 Maximum Displacement of the Blade as a Function of Maximum Load for BD2 5.4.11

Figure 5.4.4 Maximum Displacement of the Blade as a Function of Maximum Load for BD3 5.4.12
Figure 5.4.5 Maximum Blade Displacement Correlations Between the Gauges 5.4.14
Figure 5.4.6 Maximum Strains of the Blade as a Function of Maximum Load at BS3 5.4.15
Figure 5.4.7 Maximum Strains of the Blade as a Function of Maximum Load at BR1B and BR2B 5.4.16
Figure 5.4.8 Correlation Between the Rosette Strains at BR2 5.4.17
Figure 5.4.9 Correlation Between the Rosette Strains at BR1 5.4.18
Figure 5.4.10 Maximum Strain at BS9 as a Function of Minimum Strain at BS8 5.4.19
Figure 5.4.11 Maximum Strains at BR2 as a Function of Minimum Strains at BR1 5.4.20
Figure 5.4.12 Residual Plastic Deformation as a Function of Peak Displacement for BD1 5.4.22
Figure 5.4.13 Residual Plastic Deformation as a Function of Peak Displacement for BD2 5.4.23
Figure 5.4.14 Residual Plastic Deformation as a Function of Peak Displacement for BD3 5.4.24
Figure 5.4.15 Residual Plastic Deformation as a Function of Peak Displacement for All Locations 5.4.25
Figure 5.4.16 Peak Principle Stresses at Rosette Locations Versus Peak Load 5.4.29
Figure 5.4.17 Strain Gauge Readings; Test #1 5.4.29
Figure 5.4.18 Strain Gauge Readings; Test #9 5.4.30
Figure 5.4.19 Strain Gauge Readings; Test #18 5.4.31
Figure 5.4.20 Strain Gauge Readings; Test #1 5.4.32
Figure 5.4.21 Strain Gauge Readings; Test #19 5.4.33
Figure 5.4.22 Strain Gauge Readings; Test #1 5.4.34
Figure 5.4.23 Strain Gauge Readings; Test #19 5.4.35

Figure 5.5.1 Residual Plastic Deformations as Functions of Peak Loads 5.5.2
Figure 5.5.2 Maximum Load Strains as a Function of Maximum Blade Loads 5.5.3
Figure 5.5.3 Onset of Yield at the Gauge Location as a Function of Maximum Load 5.5.4
Figure 5.5.4 Onset of Yield at the Gauge Location as a Function of Maximum Load 5.5.5

Figure 5.6.1 Dependence of Total Impact Energy on the Initial Contact Area 5.6.10
Figure 5.6.2 Work to Fail Ice and Reach Peak Load 5.6.11
Figure 5.6.3 Work to Fail Ice (First Peak) as a Function of Contact Area 5.6.12
Figure 5.6.4 Dependence of Impact Power on the Speed of Advance 5.6.13

Figure 5.6.5	Total Load and Blade Displacement for for Test #14	5.6.15
Figure 5.6.6	Displacement Versus Total Load AD BD1	5.6.16
Figure 5.6.7	Blade Displacement Versus Total Load for Test #18	5.6.17
Figure 5.6.8	Strain/Load Curve for Test #19	5.6.18
Figure 5.6.9	Simplified Strain/Load Curves for Test #19	5.6.19
Figure 6.1	Centrifugal Force on Bent Blade/Centrifugal Force on Straight Blade	6.4
Figure 6.2	Centrifugal Restoring Moment as a Function of Bent Blade Geometry	6.5

LIST OF TABLES

CHAPTER 3: PROPERTIES OF THE BLADE

Table 3.1 Principal Characteristics of the Blade 3.1
Table 3.2 Propeller Material Characteristics 3.8
Table 3.3 Regression Analysis for the Kigoriak Blade Sections 3.10
Table 3.4 Reference Blade Forces 3.2
Table 3.5 Onset of Yield for Cunial 3.3
Table 3.6 Natural Frequencies of Vibrations 3.3

CHAPTER 4: TESTS SUMMARY

Table 4.1 Transducer Designation Table 4.12
Table 4.2 Blade Thickness at Strain Gauges 4.13
Table 4.3 Geometric Centres of Load Application 4.1
Table 4.4 Summary of Ice Impact Tests 4.15
Table 4.5 Maximum Values Recorded/Peak Loads 4.2

CHAPTER 5: DATA ANALYSIS

Table 5.1.1 Ice Failure Loads and Post Failure Loads 5.1.6
Table 5.1.2 Thickness Exponent for Extrusion Tests 5.1.4

Table 5.2.1 Locations of the Center of Effort for all Tests 5.2.6

Table 5.3.1 Pressures Measured During the Tests 5.3.11
Table 5.3.2 Characteristics of the Peak Pressures 5.3.14

Table 5.4.1 Summary of Displacements and Strains 5.4.8
Table 5.4.2 Gauge Readings That Exceed Yield of Material 5.4.1
Table 5.4.3 Regression Results Displacment/Maximum Load 5.4.13
Table 5.4.4 Peak and Residual Plastic Deformations 5.4.21
Table 5.4.5 Summary of Strains and Stresses 5.4.26
Table 5.4.6 Uniaxial Stresses in the Elastic and Post Elastic Domains 5.4.22

Table 5.6.1 Work of Indentation/Summary 5.6.9
Table 5.6.2 Test Maximum Strains Squared 5.6.14

1. INTRODUCTION

The propellers of arctic class ships **fail continuously.**
In order to gain some understanding of ice/propeller interaction a series of full scale simulations of ice impacts on the ice strengthened propeller blade were undertaken by GEOTECHnical Resources Ltd and Arctic Research and Development Ltd, in the Summer of 1988.

Reference 1 describes the details of the instrumentation, tests and data collected.

This report contains the analysis of the test data.
The work is based solely on the compilation of test data provided by GEOTECHnical Resources Ltd (Reference 1) and the video recordings of the tests.

2. OBJECTIVES OF DATA ANALYSIS

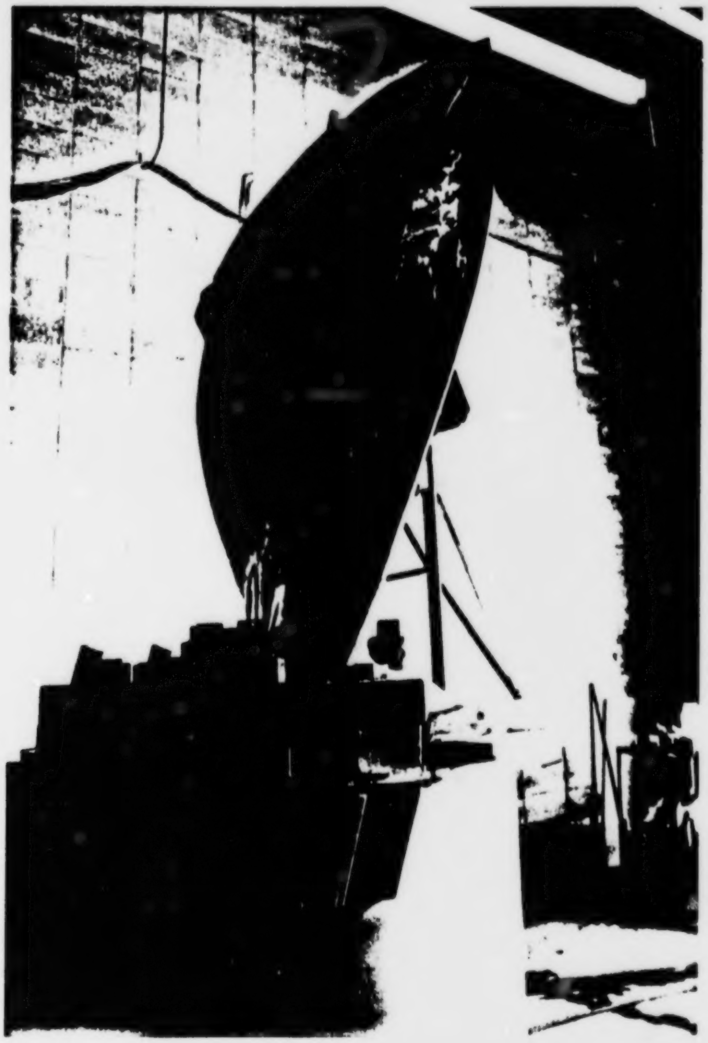
Overall objective

The overall objective of the data analysis is to **gain an** understanding of ice pressure on the blade and the blade response to it.

Specific objectives of data analysis

These are :

* Calculate effective locations of ice load application.
* Analyze the pressure distribution across the ice interaction zone.
* Compare the applied loading with the blade strain, stress and displacement response, both elastic and plastic.
* Identify the force levels at which blade deformation occurs.
* Quantify the energy aspects of the interaction, in particular in the post elastic region of response.
* Comment on the engineering significance of the test results.
* Provide conclusions and recommendations.



3. PROPERTIES OF THE BLADE.

3.1 Principal characteristics of the blade

The blade used for the tests was that of the shrouded CPP propeller, of ASPPR ice class 3 icebreaking supply and anchor handling vessel, MV CANMAR KIGORIAK.

The relevant parameters of the blade are:

TABLE 3.1

PRINCIPAL CHARACTERISTICS OF THE BLADE

Blade length tip to root	1.800 m
Blade length base to tip	1.965 m
Maximum expanded width	2.178 m
Blade expanded area	3.25 m^2
Blade contour	Mod. Kaplan
Blade mass	2670 kg
Direction of rotation	left hand
Material:	CUNIAL (Lips)
Ice Class notation:	ASPPR 3

Detailed geometric characteristics of the blade are shown in Figure 3.1.

Figure 3.2 gives the pitch distribution along the blade together with the angular twist of the blade, referred to the blade root.

Figure 3.3 gives the maximum thickness distribution along the blade.

Table 3.2. contains the detail strength characteristics and other relevant properties of the blade material.

Figure 3.4 shows the calculated (using approximate method):

moment of inertia and
section modulus

distribution along the blade radius.

Table 3.3 shows the results of the calculations and the best fit equations for the inertia and section modulae distribution along the blade.

For the comparison with the test data the following calculated forces can be used as a reference:

TABLE 3.4

REFERENCE BLADE FORCES

blade weight:	26 kN
blade thrust at the bollard:	202 kN
calculated* ultimate load when applied at the center:	1,838 kN
calculated* ultimate load when applied at the l.e.:	1,125 kN
Point of the load application:	0.9 r/R

note: * supplied by the blade manufacturer.

Appendix A contains detailed drawings of the blade, blade palm and other characteristics of the blade.

The strain causing yield of the material is :

$$ey = SY/E = 260\ MPa/130000\ MPa = \mathbf{2{,}000\ microstrains.}$$

The strain corresponding to the ultimate tensile strength of the material is:

$$\mathbf{eu = 0.2\ \ (200{,}000\ microstrains)}$$

The reference linear strain corresponding to the ultimate tensile strength of the material is

$$euref = UTS/E = 640MPa/130000\ MPa = 4{,}923\ microstrains$$

The yield strength of the material depends on the thickness of the specimen tested. The values typically used are shown in TABLE 3.5. Yield stresses at the gauge locations are shown in Figure 3.8. The simplified stain/stress relationships for CUNIAL are shown in Figure 3.9. Figure 3.10 shows the simplified stress/strain relationship in the post-elastic domain, which is used for the computation of the stresses in that range.

TABLE 3.5

ONSET OF YIELD FOR CUNIAL

Specimen thickness, mm	Onset of yield, MPa
20	**245**
100	**200**
500	**120**

3.2 Natural vibrations frequencies in air.

Tests 16 and 17 were done in order to establish the natural frequency of the blade in flexural vibrations. A sledge hammer was applied at the locations shown in Figure 3.5.
The resultant vibrations are recorded in Figures 3.6 and 3.7.
The following table has been compiled based on the analysis of the vibrations:

TABLE 3.6

Natural frequencies of vibrations

impact	first	second	third	fourth
off -center (#16)	32	109	125	**237**
center (#17)	32	**109**	237	

The frequency of 32 Hz is associated with the vibrations of the blade as a rigid body attached to the elastic foundation.

The frequency of 109 Hz is the dominant flexural frequency, strongly present in both tests. The frequency of 125 Hz is the first mode torsional frequency. The frequency of 237Hz is the second, dominant frequency in torsion.

For a comparison with the calculated values, the following equation has been used :

$$\text{frequency} = 0.18 * (tr/l^2)*(cr*ta*E/cra/tr/ro)^{0.5} \qquad 3.1$$

where:

tr is the root thickness, in m	(0.242)
l is the blade length, in m	(1.800)
cr is the root chord, in m	(1.030)
ta is the average thickness of the blade, in m	(0.070)
E is the elastic modulus of the material, in Pa	($1.30*10^{11}$)

cra is the average chord length of the blade, in m (1.810)
ro is the mass density of the blade material, in kg/m^3 (7600)
Frequency is given in Hz.

Computation yields:

f(air) = ***112 Hz.***

Agreement between the measured and computed values is good (within 3%).

The vibrations tests show that the blade vibrates in the combined flexural and torsional modes, regardless of the point of application of the load.

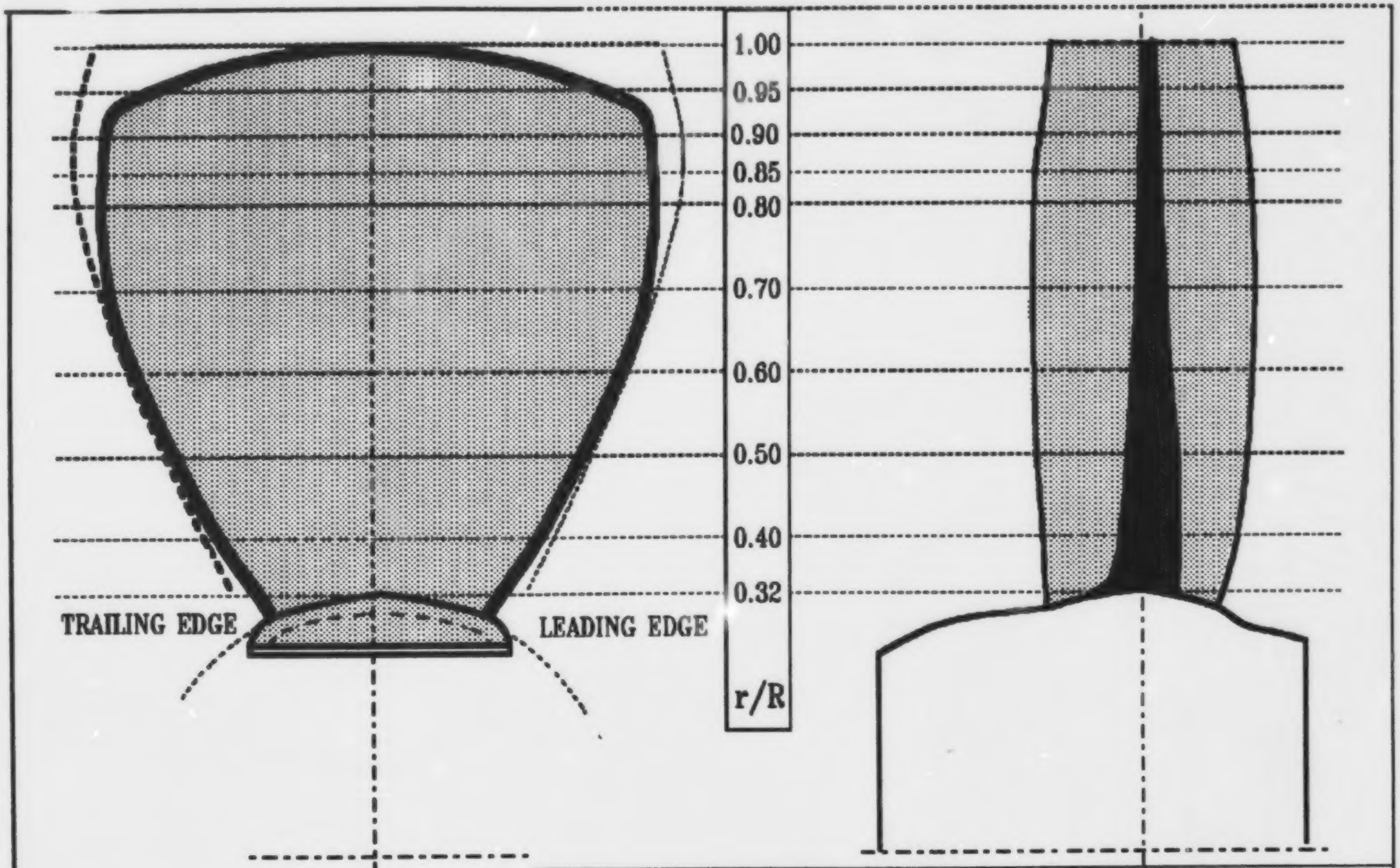

TRAILING EDGE
LEADING EDGE
1.00
0.95
0.90
0.85
0.80
0.70
0.60
0.50
0.40
0.32
r/R

FIGURE TITLE: BLADE GEOMETRY

PROJECT NAME: FULL SCALE TESTS ON THE BLADE RESPONSE

DRAWN BY: VL	CHK'D BY: VL	SCALE: 20.5:1	FIGURE NR: 3.1

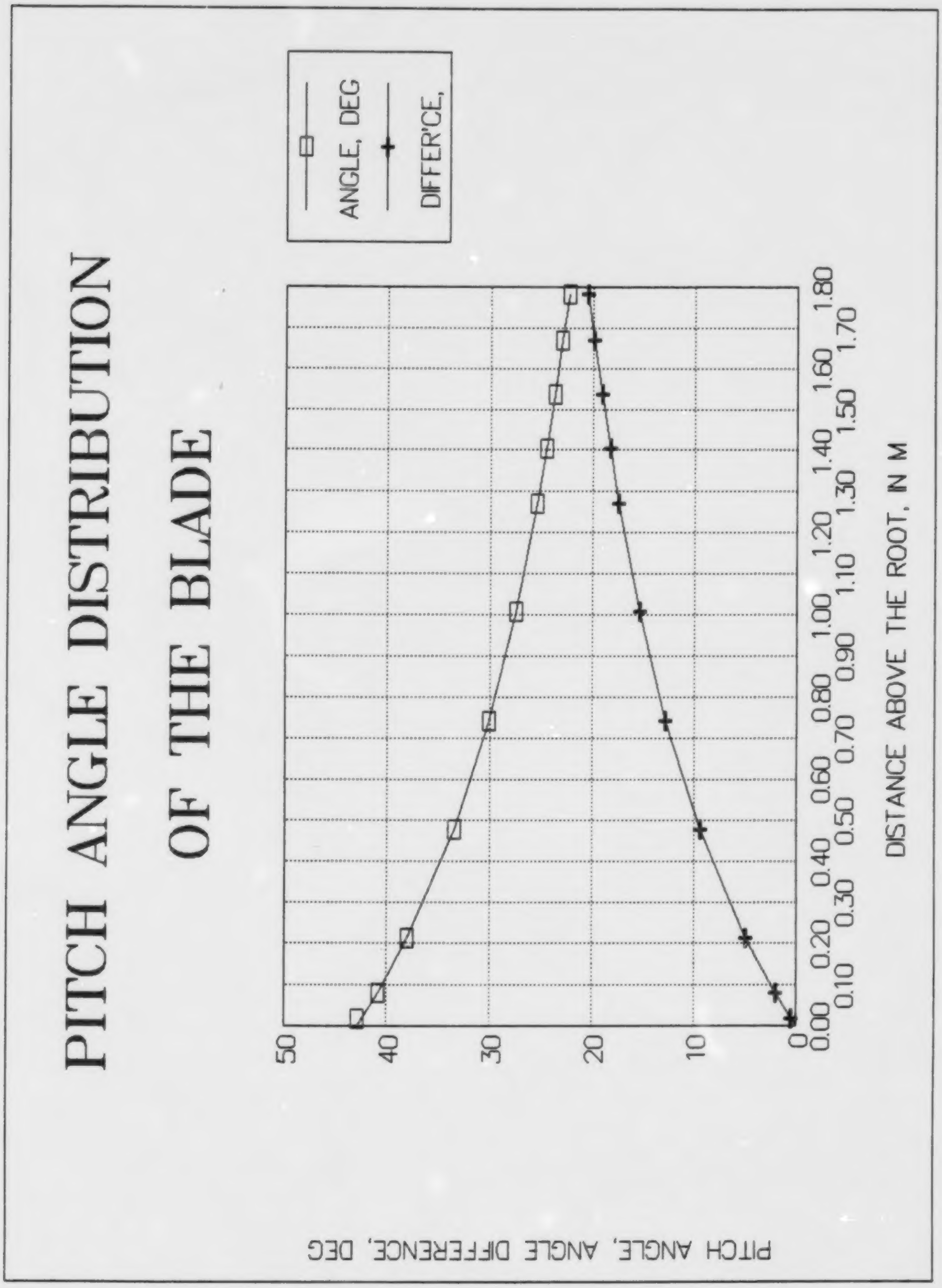

PITCH ANGLE DISTRIBUTION
OF THE BLADE
ANGLE, DEG
DIFFER'CE,
PITCH ANGLE, ANGLE DIFFERENCE, DEG
0
10
20
30
40
50
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
1.10
1.20
1.30
1.40
1.50
1.60
1.70
1.80
DISTANCE ABOVE THE ROOT, IN M

FIGURE 3.2

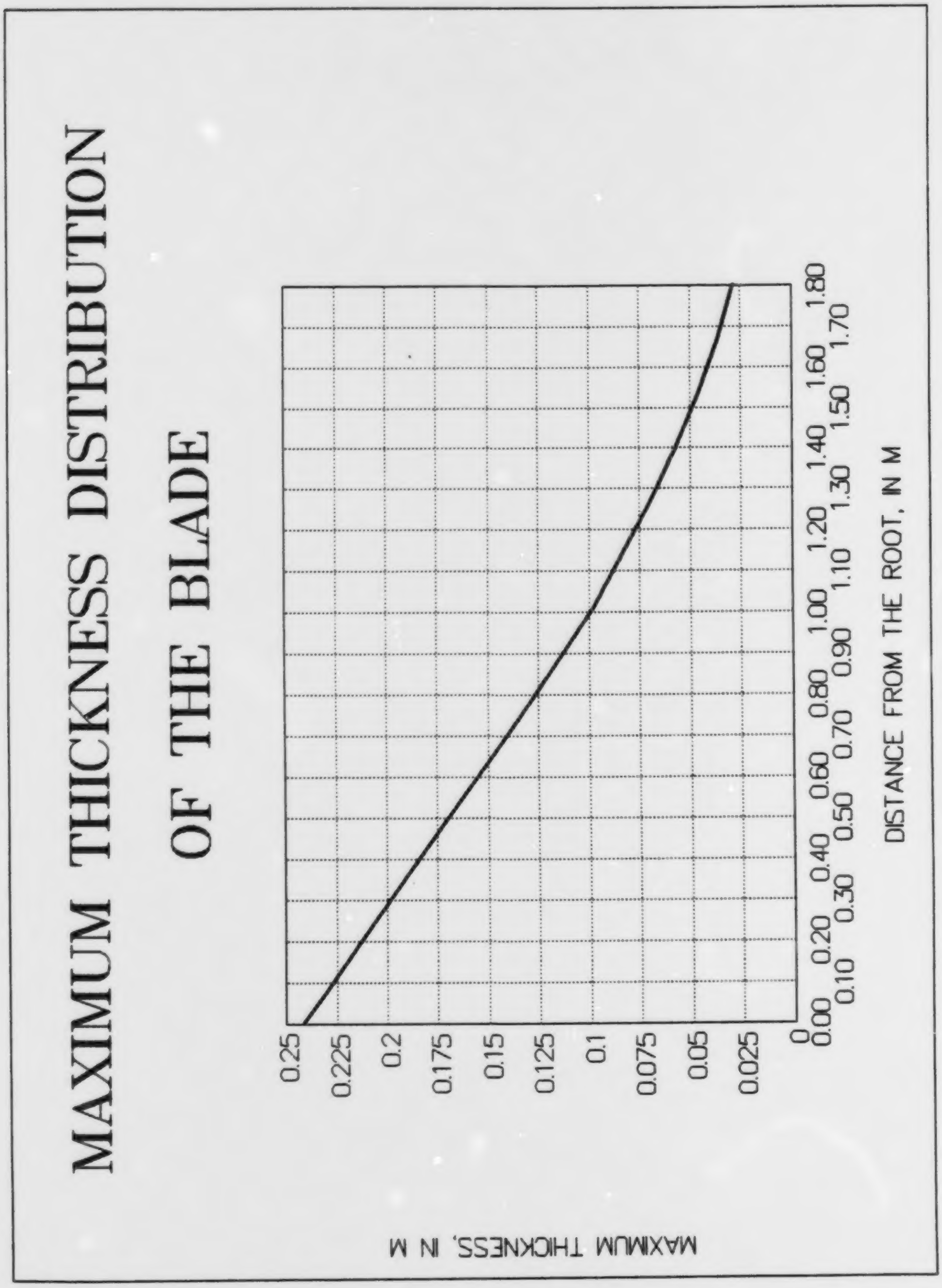

MAXIMUM THICKNESS DISTRIBUTION OF THE BLADE

Figure 3.3

TABLE 3.2
PROPELLER MATERIAL CHARACTERISTICS

MATERIAL		DESIGN CUNIAL FOR BLADE
PHYSICAL PROPERTIES:	UNITS	
DENSITY	kg/m^3	7600
ELASTIC MODULUS	GPa	130
POISSON RATIO		0.3
BRINELL HARDESS		160
STRENGTH PROPERTIES	UNITS	
U.T.S.	MPa	640
YIELD POINT	MPa	260
ELONGATION	%	20
IMPACT VALUE/CHARPY	J/cm^2	
FAT. STRGTH IN AIR	MPa	
FAT. STRGTH IN SEA	MPa	
0.2% PROOF STRESS	MPa	
0.1% PROOF STRESS	MPa	
COR. FAT. ENDUR. IN SEAWATER	MPa	167
CAV. COR. RES. IN SEA (COMP. WITH LIMA 15=1)		
CHEMICAL PROPERTIES	UNITS	
C	%	
Cr	%	
Ni	%	4.5
Fe	%	4.5
Al	%	9.5
Zn	%	0
Cu	%	80.5
Mn	%	1
Mo	%	
Si	%	
Sn	%	
Pb	%	
Sn+Pb	%	
Al+Mn+Zn	%	10.5
Fe+Ni	%	9

Figure 3.4

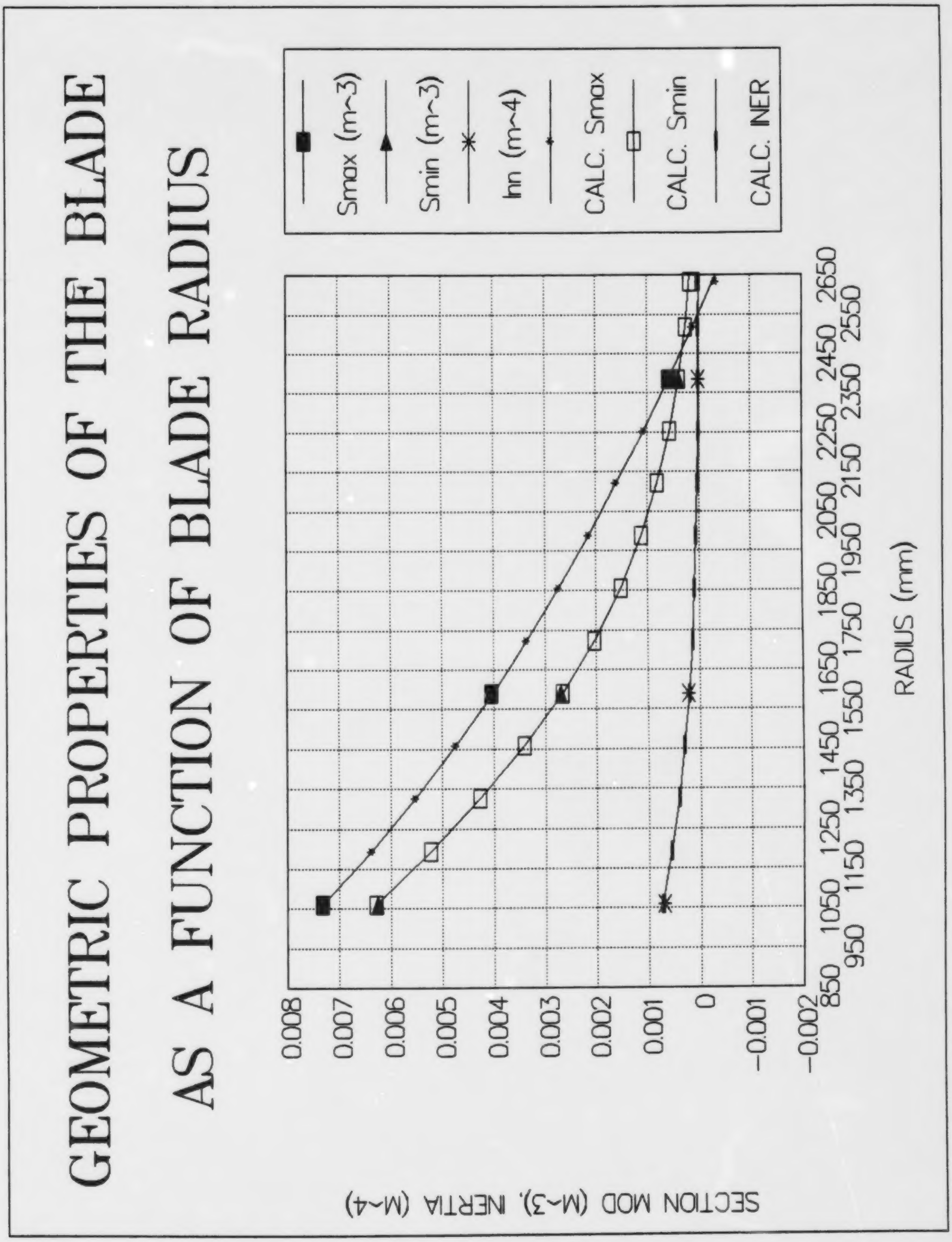

GEOMETRIC PROPERTIES OF THE BLADE
AS A FUNCTION OF BLADE RADIUS
SECTION MOD (M~3), INERTIA (M~4)
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
-0.001
-0.002
850
950
1050
1150
1250
1350
1450
1550
1650
1750
1850
1950
2050
2150
2250
2350
2450
2550
2650
RADIUS (mm)
Smax (m~3)
Smin (m~3)
Inn (m~4)
CALC. Smax
CALC. Smin
CALC. INER

TABLE 3.3

ARCTIC RESEARCH AND DEVELOPMENT LTD.

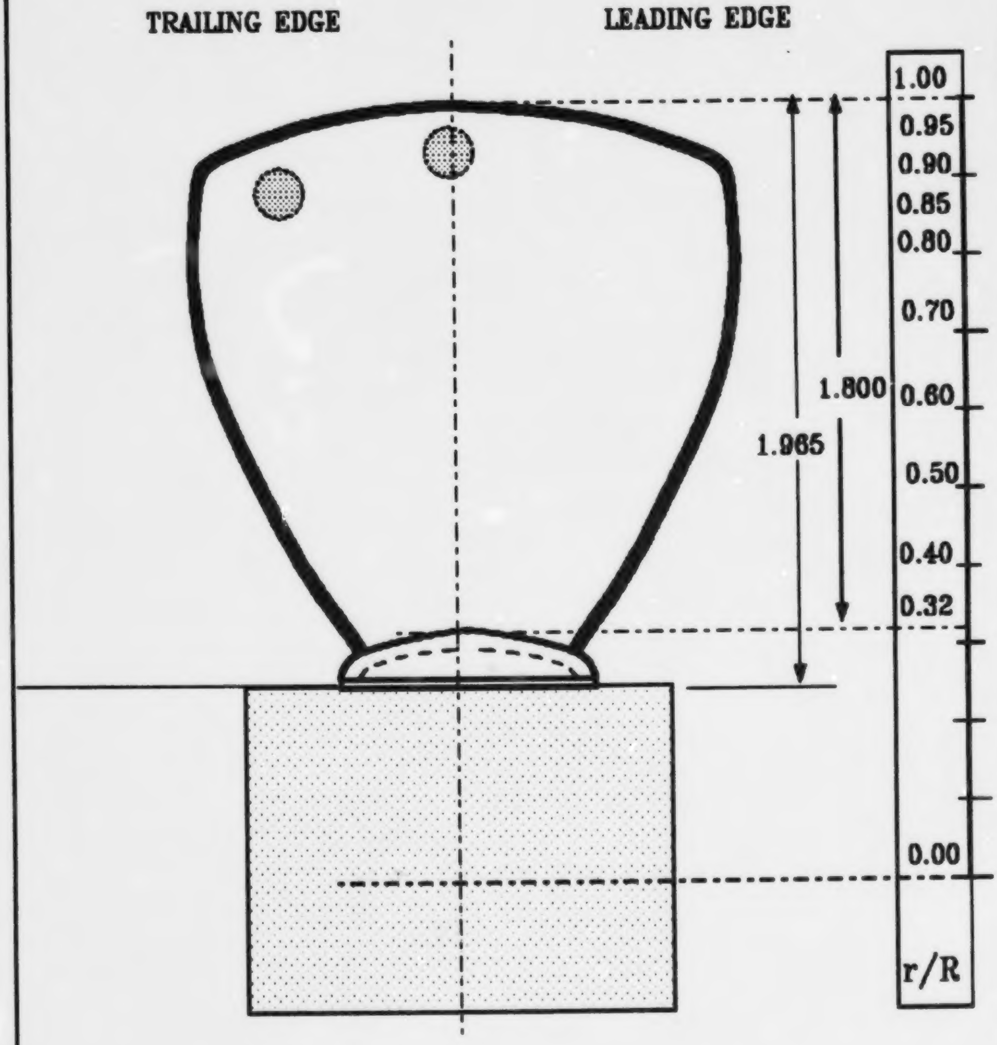
REGRESSION ANALYSIS FOR THE KIGORIAK BLADE SECTIONS

RADIUS (mm)	Smax (m^3) CALC.	Smax (m^3) ACT.	Smin (m^3) CALC.	Smin (m^3) ACT.	I (m^4) CALC.	I (m^4) ACT.
1060	0.007326	0.007325	0.006282	0.006250	0.000739	0.000708
1192.5	0.006380		0.005236		0.000565	
1325	0.005525		0.004272		0.000418	
1457.5	0.004744		0.003412		0.000300	
1590	0.004024	0.004045	0.002667	0.002704	0.000209	0.000219
1722.5	0.003356		0.002041		0.000141	
1855	0.002733		0.001528		0.000092	
1987.5	0.002149		0.001120		0.000058	
2120	0.001599		0.000804		0.000036	
2252.5	0.001079		0.000564		0.000021	
2385	0.000585	0.000585	0.000388	0.000390	0.000012	0.000012
2517.5	0.000116		0.000261		0.000007	
2650	-0.00033		0.000172		0.000004	

$Smax = 0.087121 - 0.03976 * R^{0.1}$

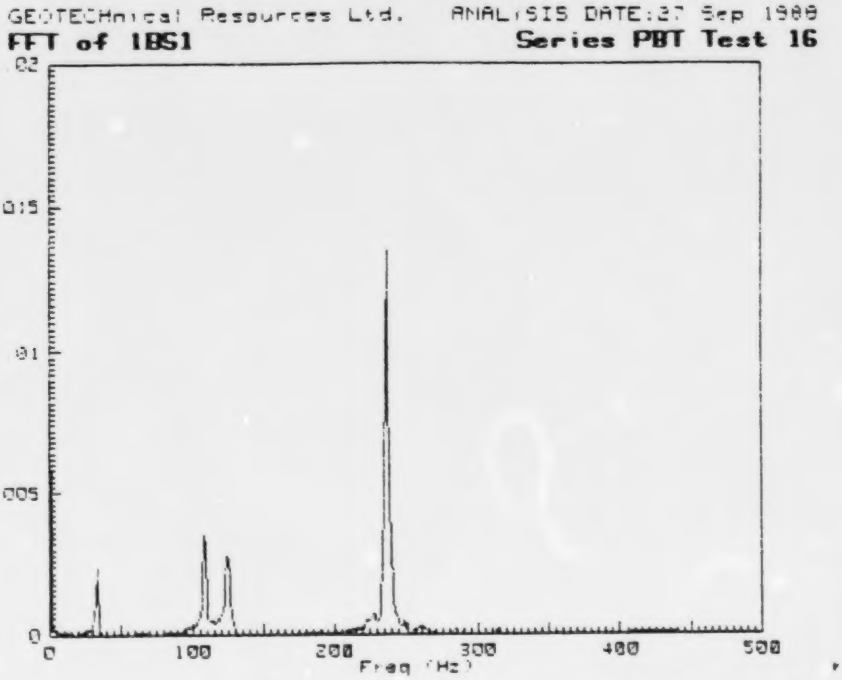
$Smin = 0.012467 * \exp(R^{2})$

$I = 0.002031 * \exp(R^{2})$


TRAILING EDGE
LEADING EDGE
1.00
0.95
0.90
0.85
0.80
0.70
1.800
0.60
1.965
0.50
0.40
0.32
0.00
r/R

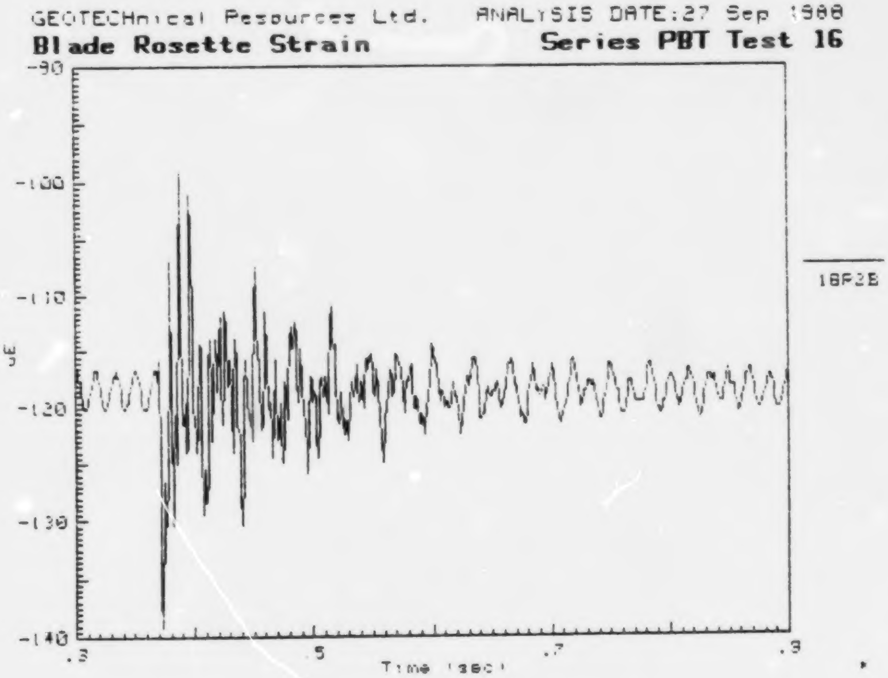
BLADE CONTOUR LOOKING AFT

FIGURE TITLE: LOCATION OF IMPACT POINTS FOR VIBRATION TESTS			
PROJECT NAME: FULL SCALE TESTS ON THE BLADE RESPONSE TO ICE			
DRAWN BY: VL	CHK'D BY: VL	SCALE: NONE	FIGURE NR: 3.5



GEOTECHnical Resources Ltd.   ANALYSIS DATE:27 Sep 1988

FFT of 1BS1   **Series PBT Test 16**



GEOTECHnical Resources Ltd.   ANALYSIS DATE:27 Sep 1988

Blade Rosette Strain   **Series PBT Test 16**

FIGURE 3.6

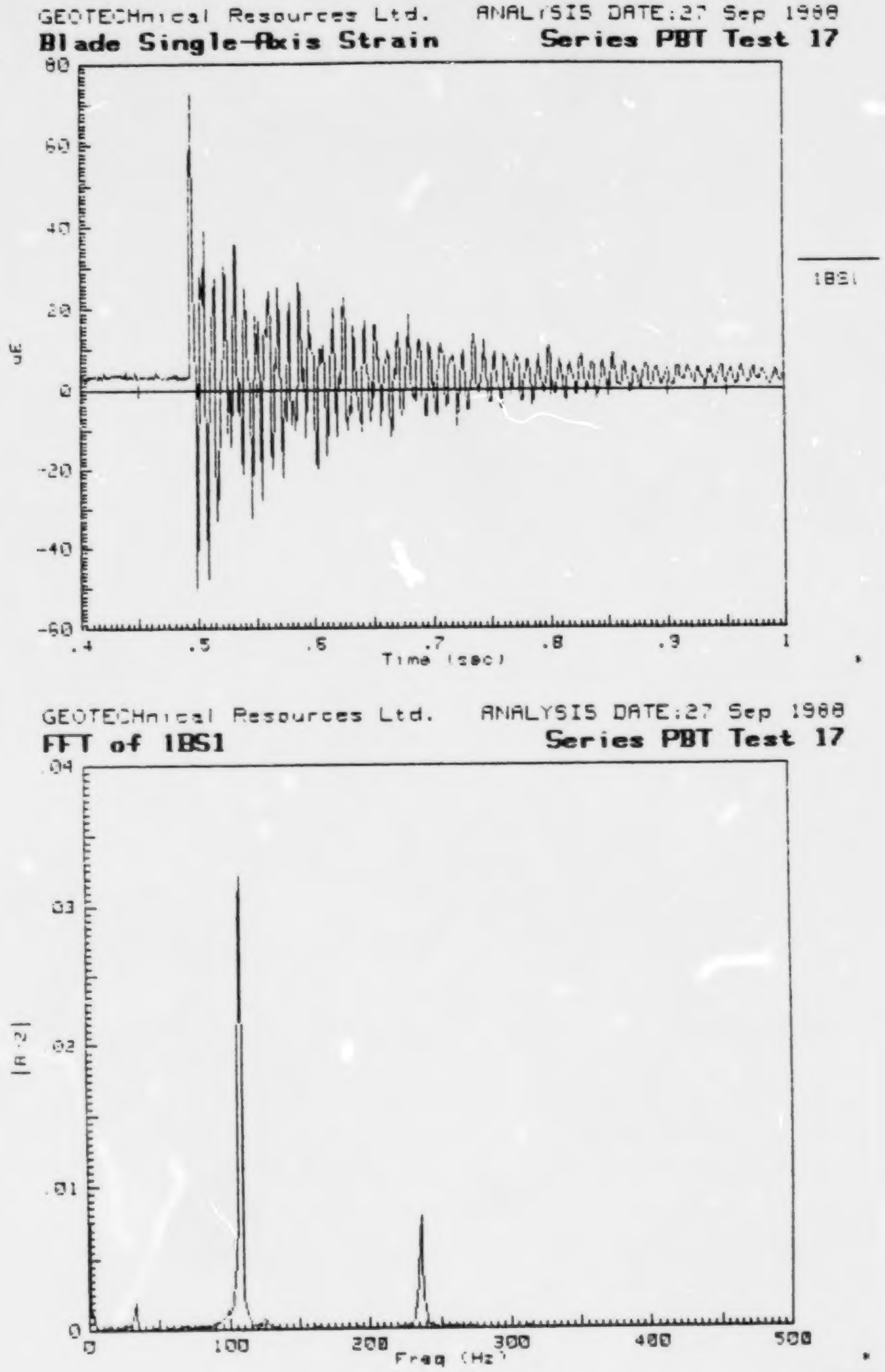

GEOTECHnical Resources Ltd.
ANALYSIS DATE:27 Sep 1988
Blade Single-Axis Strain
Series PBT Test 17
80
60
40
20
0
-20
-40
-60
uE
.4
.5
.6
.7
.8
.9
1
Time (sec)
1BS1
GEOTECHnical Resources Ltd.
ANALYSIS DATE:27 Sep 1988
FFT of 1BS1
Series PBT Test 17
.04
.03
.02
.01
0
|A^2|
0
100
200
300
400
500
Freq (Hz)

FIGURE 3.7

Figure 3.8.

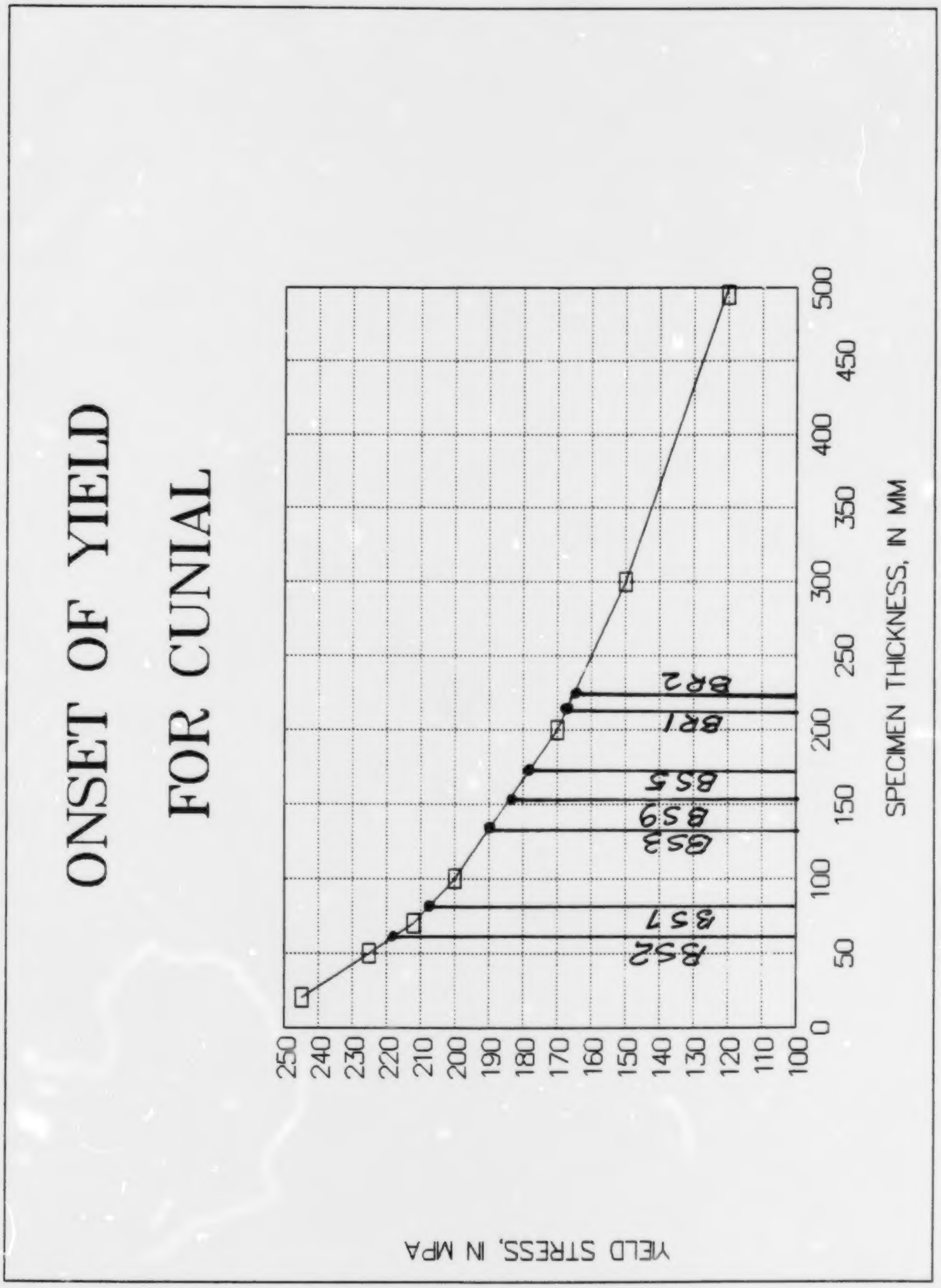
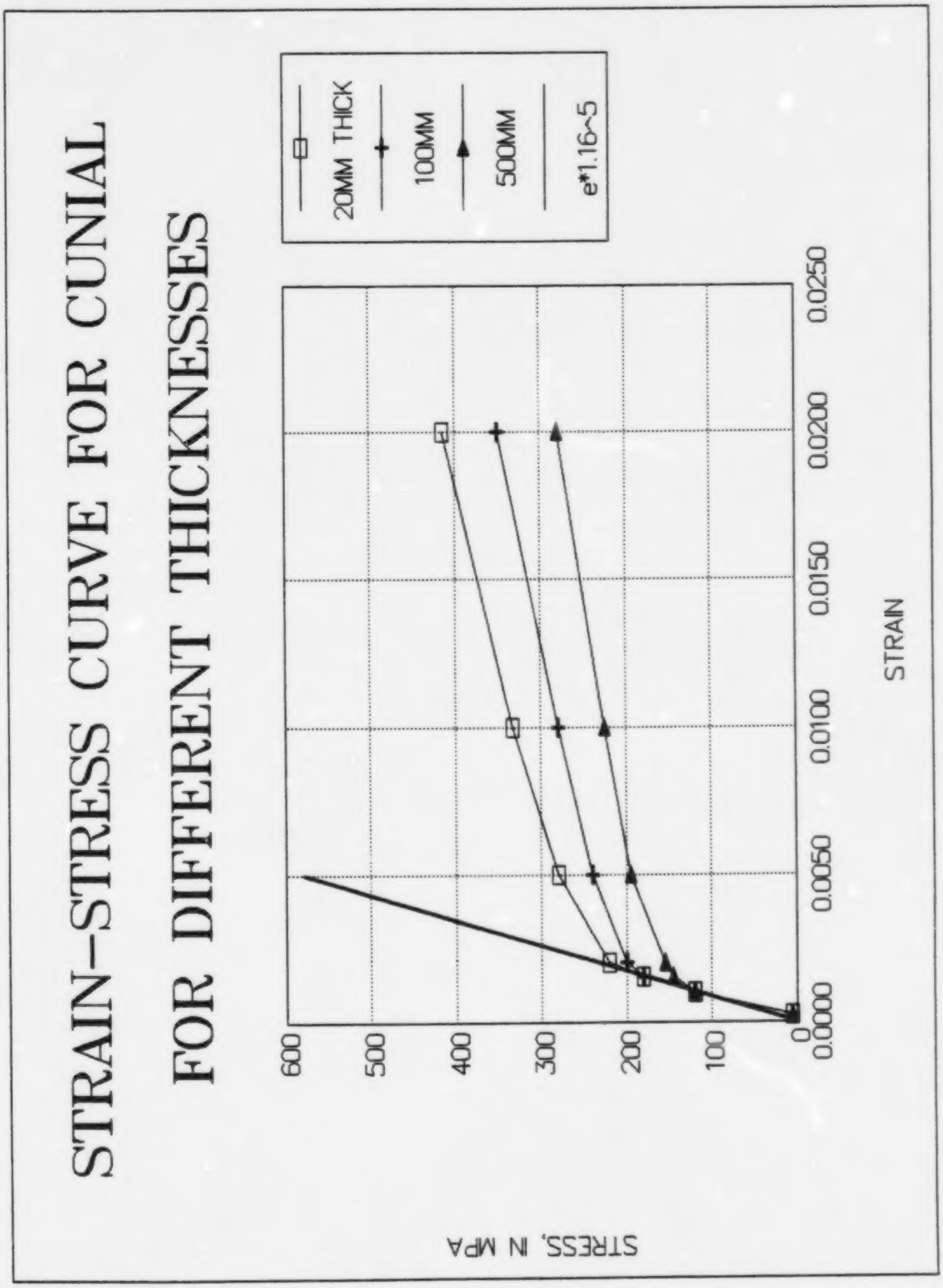

ONSET OF YIELD
FOR CUNIAL
YIELD STRESS, IN MPA
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
SPECIMEN THICKNESS, IN MM
0
50
100
150
200
250
300
350
400
450
500
BS2
BS7
BS3
BS9
BS5
BR1
BR2

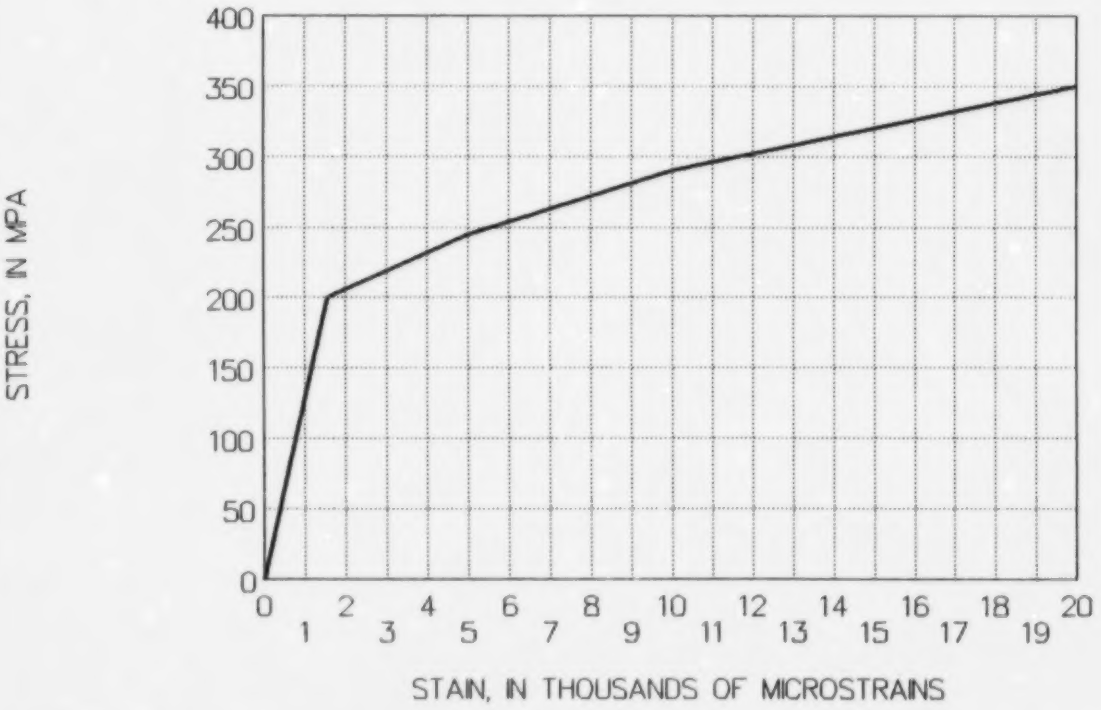
FIGURE 3.9



STRAIN-STRESS CURVE FOR CUNIAL
FOR DIFFERENT THICKNESSES

FIGURE 3.12

SIMPLIFIED STRESS/STRAIN CURVE FOR CUNIAL IN THE POST-ELASTIC DOMAIN



4. TESTS SUMMARY

4.1 Tests setup

The schematic of the testing apparatus is shown in Figure 4.1. The position of the blade gauges is shown in Figure 4.2a and b. Table 4.1 gives the transducer designation and description.

The following signals were collected:

1 Command
6 actuator pressure gauges
3 actuator extensiometers
5 pressure transducers installed on the upper part of the blade
2 blade strain rosettes installed in the lower part of the blade
9 blade strain gauges on the suction and pressure side.
3 blade extensiometers
3 frame strain gauges
1 Frame backstop strain

A video camera and a number of still photo cameras were recording the tests in progress.

Table 4.2 gives the thickness of the blade at the location of the gauges. Statistics of the collected signals are given in the Appendix C. Photographs F1 and F2 show the typical test in progress.

Altogether 19 tests were carried out until the destruction of the blade (large permanent deformation). Test variable were:

ice strength

load application area

speed of advance

The blade was loaded on the pressure side.

The geometric center of the three rams triangle was located as follows:

TABLE 4.3

GEOMETRIC CENTERS OF LOAD APPLICATION

Tests	vertical elevation above the base m	horizontal offset towards the l.e. m
1 - 6	1.433	0.000
7 - 19	1.639	0.384

4.2 Tests execution

Table 4.4 summarizes all of the tests done, together with the tests statistics.

The driving speed was preset with the command signal and kept constant throughout the test. Blade strains and displacements were measured continuously. The pressure in the ram cylinders was also measured and it served as a trigger for termination of rams advancement.

Test 13 was aborted due to mechanical failure. Tests 16 and 17 were done for the purpose of determining the natural vibration frequencies of the blade in air.

Tests 18 and 19 were done using timber instead of ice in order to exert the maximum force possible on the blade.

The speed of advance of the rams was varied from 0.003 m/s to 0.103 m/s which is representative of the slow motion of a ship ahead or astern.

4.3 Tests results/ maxima recorded

Table 4.5 gives the maximum values recorded during the tests.

TABLE 4.5

MAXIMUM VALUES RECORDED/PEAK LOADS

PARAMETER	VALUE	GAUGE	TEST
blade load, MN	**3.93**	AL1 + AL2 + Al3	15
blade pressure, MPa	**29.0**	BP3	15
blade strain, microstr	**10,000**	BR, BS	18,19
blade displacement,m	**-0.186**	BD2	19

Reference 1 gives the details of the tests conducted, instrumentation and calibrations used.

Appendix B gives the traces of the maximum load signals for all the tests.

4.4 Description of individual tests

In order to gain some insight into the data, a brief description of each tests ice/propeller interaction has been prepared. (Note: the numbers given in this paragraph are uncorrected. See the tables for the corrected values).

Test 1

Ice was prepared from 4 individual blocks flooded and frozen together. A rectangular contact area was shaped in front of the steel bucket of approximate dimensions ***1m X 1m.*** *Speed of advance was set to* ***0.0915 m/s.*** *Contact area was on the centerline of the blade.*

The total load on the blade is shown in Figure 5.1. The following phases of interaction are apparent:

loading	*(0.5 to 0.9 sec)*
failure	*(0.9 to 1.1 sec)*
extrusion	*(1.1 to 2.3 sec)*
reloading	*(2.2 to 3.1 sec)*
creep	*(3.2 to 5.0 sec)*

The interaction was characteristic of the "brittle" type, with large chunks of ice being violently pushed out of the contact zone.

Note that after the bulk failure at 0.9 sec, the load drops to approximately ***1/2*** *of the failure force of* ***0.42 MN.*** *The maximum load recorded at the end of the indentation was* ***0.68 MN,*** *while the maximum blade pressure recorded was* ***8.15 MPa.***

Test 2

Ice was prepared from the crushed ice left from the previous test. Initial contact area was shaped to be circular, having an area of ***1.54 m^2.*** *The speed was preset at* ***0.0857 m/s.*** *Ice temperature was* ***-18 deg C.*** *Contact point was central.*

Quick loading lead smoothly to the total load peak of ***0.53 MN,*** *after which the actuators retracted. No global ice failure was noticed, since the total load has triggered actuators retraction. The maximum blade pressure recorded was* ***1.11 MPa.***

Test 3

Crushed ice was frozen together and shaped to form a circular contact area of approx ***1.2 m^2.*** *Ice temperature was* ***-16.8 deg C.*** *Bottom part of the circular contact area was removed, as it had been damaged in the previous test. Contact point was central. Speed of the actuator was set at* ***0.0835 m/s.*** *Loading phase was smooth and no major failures were noticed. After reaching the peak load of* ***0.58 MN,*** *the actuators retracted. Maximum blade pressure recorded was* ***6.06 MPa.***

Test 4

Most ice from the previous tests was replaced. A rectangular contact area **(0.65m X 1.09 m)** was shaped up to fit the surface of the blade. This area protruded 0.3m out of the steel confining bucket. The speed was set at **0.1m/s.** Contact point was central. After the initial contact was made, the first brittle failure occurred at 1 sec., after which the load dropped to zero and loading restarted again. The peak load was achieved at 2.7 sec, of the magnitude of **1 MN.** The loading curve was exponential. Violent extrusion of large chunks of ice was characteristic to the whole test.Crushing of the protruding ice mass was clearly visible. Blade surface pressures showed oscillatory behavior at approx. **130 Hz.** The peak pressure recorded was **8.41 MPa.**

Test 5
A triangular shaped contact area **(1.0m X 1.2m)** was prepared from the crushed ice. This area protruded 0.3m out of the steel bucket. Ice temperature was **-10 deg C**. Advance speed was set at 0.1 m/s. Contact point was central.
After initial contact area was developed, a local failure of ice took place, due to the mismatch of the blade and ice surfaces. Exponential load growth followed, resulting in a peak load of **0.4** MN. Instant flaking and extrusion of ice was observed during the tests. Retraction of the actuators was caused by the unsymmetrical load distribution between the cylinders. Peak surface pressure recorded was **2.28 MPa.**

Test 6
This test was a continuation of the test 5. Ice surface temperature was **-5 deg C.** The contact surface was rectangular, and reduced to **0.1 m^2.** Speed of advance was set at **0.105m/s.** Contact point was central.
Initial loading was followed by a failure at approximately 1.8 sec into the test. Ice was first compressed into the bucket and the initial flaking and extrusion took place there, rather than on the contact surface. Load dropped to approximately 1/2 of the initial peak, after which it regained its peak value. At 2.2 sec into the test, another major failure occurred and the load dropped. Reloading followed until the peak of **0.6 MN** was reached. Peak pressure reached was **3.62 MPa.**

Test 7
Ice was prepared from crushed ice shaped into a circular contact area of **0.38 m^2.** This area protruded approx 10 cm from the main bulk of the ice contained in the bucket. The speed was set at **0.1027 m/s.** Contact point was off-center (see Figure 4.3). Initial loading resulted in a local failure, after which the load dropped to approximately 1/2 of its peak value. Reloading took place from 1 to 2.8 sec. A peak load of **0.37 MN** was reached at approx 2.8 sec, followed by a period of relaxation with the load dropping steadily to about 1/2 of the peak value. The peak blade pressure was **4.16 MPa.**

Test 8
Crushed ice was shaped into a circular contact area of **0.68 m^2,** protruding some 0.4 m out of the bucket. The speed was set to **0.1** m/s. Contact point was off-center.
Smooth loading phase lead to the initial peak of **0.53 MN,** at which a brittle failure occurred, followed by a period of no load. The distance travelled by the rams after the initial failure was 0.1 m during which no load was recorded. Reloading took place at 2.6 sec into the test after which the load stabilized due to the ram stoppage. Peak pressure recorded was **7.16 MPa.** After the initial small compression, the large blocks extrusion process lasted throughout the test, accompanied by pronounced flaking of the sides of the ice cylinder.

Test 9
Ice was prepared from the crushed particles, flooded and frozen together. Contact surface was shaped into circular area of **1.25 m^2.** This area protruded some 15 cm out of the bucket. Speed was set at **0.1m/s**. Contact point was off-center.
Initial loading resulted in a local failure (load dropped to 1/2 of the peak value) after which rapid reloading took place, ending in a peak load of **1.23 MN.** Failure of ice occurred at 2.3 sec into the test, after which the total load dropped to less than 1/2 of the peak load. Reloading immediately followed, ended by the stoppage of the rams. A relaxation period followed from 2.7 sec to 5.3 sec, during which time load dropped to 1/2 of its peak post failure value. Blade showed pronounced vibratory behavior after the ice failure at 2.3 sec, oscillating about the position of 1/2 of the peak displacement. The peak recorded pressure was **7.54 MPa.** The extrusion of ice was continuous, accompanied by a nearly explosion -like extrusion towards the end of the test (2.3 sec), when a hard block of ice was destroyed.

Test 10
Ice was the same as in the previous tests. Contact area was **0.91** m^2, protruding a little out of the bucket. The speed was set at **0.103 m/s.** Contact point was off-center.
A smooth loading phase resulted in a peak load of **0.45 MN,** after which the actuators retracted. The blade has rotated somewhat under the eccentric load, which caused the rams to retract. The peak pressure recorded was **0.40 MPa.** No extrusion process was observed, other than very local flaking near the bottom of the ice contact area.

Test 11
Ice was made of crushed particles flooded and frozen in layers and shaped to fit the blade. Same ice was used as for the previous test. Footprint was circular, with the contact area of 0.91 m^2, protruding very little out of the bucket. Speed was preset at **0.1 m/s.** Contact point was off-center.

*Smooth loading lead to the gradual failure of the ice which started at 2.2 sec into the test. Peak load of **1.15 MN** was reached during the series of local failures. Stopping of the rams resulted in rapid drop of the load to approximately 1/2 of its peak value.*
*Creeping relaxation followed with the load dropping by a further 15%. Peak pressure observed was **6.20 MPa**. Blade response was a linear one. During this phase, the displacement of the blade decreased to 1/2 of its maximum value. Pronounced extrusion took place continuously throughout this short test.*

Test 12
*Crushed ice was frozen and shaped into a circular area of **1.25 m^2, protruding some 0.2 m out of the bucket.** Speed of advance was set at **0.1m/s**. Contact point was off-center.*
*Initial loading phase lead to a series of local failures. Peak load of **1.25 MN** was reached at 1.7sec into the test, after which rapid decrease of the load to 1/2 of its peak value took place. At that level, an extrusion process took place, (1.8sec to 2.5 sec) resulting in large fluctuations of the load.*
*Reloading began at 2.5 sec, leading to the rapid rise of the total load on the blade. Peak was determined by stopping the rams, after which a creep period lead to the lowering of the load. Peak pressure recorded was **13.31 MPa.** Throughout the test the cracking and flaking of the ice protruding mass and extrusion was apparent.*

Test 13
This test was aborted due to mechanical failure.

Test 14
*Ice was made from crushed particles flooded and frozen together. Contact area was circular and had a surface of **1.25** m^2, protruding a little out of the bucket. Speed was preset at 0.003m/s. Contact point was off-center.*
*Gradual and smooth loading of the blade followed, with only small internal cracking and "sweating" of ice. The peak load of **2.05 MN** was achieved when the indentation process was stopped and the actuators retracted. A number of strain gauges recorded the strains exceeding yield and the blade showed the permanent offset of approximately **2mm** at the gauges BD1, BD2, BD3 and other. Peak pressure recorded was **12.31 MPa.** Peak strain recorded was **2,140 microstrains,** in compression, which is very near the yield strain value of 2200 microstrains. No extrusion took place throughout the whole test.*

Test 15
*Ice was the same as in the test 14, reshaped to polygon having an area of **0.60 m^2.** The geometric center of the polygon was **0.384** m off the centerline towards the leading edge at the elevation of 1.639 m above the blade base (0.326m below the blade tip).*

This position coincided with the location of pressure gauge BP3. The speed of advance was set at **0.0055m/s**.

Four phases of ice/blade interaction were noticeable:

initial loading	(20 sec to 30 sec)
bulk failure and decompression	(30 sec to 45 sec)
post failure loading	(45 sec to 54 sec)
hard impact	(54 sec to 55 sec)

Ice failed in crushing mode and small blocks extruded from the bottom of the contact area. The final surge in the pressure and load was due to some very hard ice block contacting the blade. (The scrutiny of the video movies made during the tests showed no contact between the steel bucket and the blade).
Peak load reached was **4.1 MN** at 54 sec into the test. Most of the strain gauges exceeded yield and showed large residual deformations. Peak pressure recorded was **29.0 MPa**, while the peak strain recorded was **5,000** microstrains. Blade displacement showed 10mm permanent deformation at the gauge BD3. Figure 4.4 shows the total load and actuator displacement as a function of time for this test. No extrusion process took place, other than some bottom edge flaking and loud internal ice cracking.

Test 16 and 17
These tests were done for the purpose of determining the natural vibration frequency of the blade. The blade was hit with a sledge hammer at the locations shown in Figure 3.5. Resulting vibrations showed rapid attenuation of oscillations within 1/2 sec. Blade vibrated at **109`Hz** in the fundamental mode of flexural vibrations.

Test 18
In order to assure the failure of the blade, ice was replaced with an assembly of cedar timber, arranged in a pyramidal fashion.
The initial contact area was rectangular, **0.3m^2.**
Contact point was off center. The speed was preset at **0.1 m/s**.
Loading phase was smooth. No failure was observed till the peak load of **2.1 MN** was reached at 2.6 sec, after which the actuators stopped. Pronounced relaxation of strains was observed thereafter. Blade was displaced **100 mm** at BD2. Maximum pressure recorded was **5.8 MPa.** During the loading phase, large fluctuations of the local pressure took place. Several strain gauges exceeded the yield and reached the **8,000 to 10,000** microstrains level.

Test 19
Same wood was used for this test. The contact point was

off-center. The preset speed was **0.0103m/s.** The loading was smooth, initially linear. As the wood was compressed and the blade deformed away from the actuator, slowing down of the loading become pronounced. At 2.7 sec the load reached its peak of **2.3 MN** after which the timber slipped off the blade and indentation terminated. **A 200 mm** displacement of the blade at BD2 was registered. A number of gauges reached the **10,000** microstrains level and showed permanent offset at **5,000** microstrains. The maximum contact pressure registered was **4.42** MPa. Pressure gauges showed very pronounced vibrations in response to compression of timber.

4.5 Strain rates

Table 4.6 shows the reference strain rates computed using the following equation (after Reference 1):

strain rate = V/(4*sqrt(A)..........................4.1

where v is the velocity of advance, in m/s; A is the initial contact area, in m^2, and sqrt is the square root operator.

It is clear that the most of the tests were done in the brittle range of the strain rates (s.r > 5*10^-3 1/s) while the "slow tests" correspond to the ductile/transition range of the strains. The timber tests, while done at high strain rates, are considered to be of the "ductile" type.

4.6 Miscellaneous comments on the tests

1. In all cases, the MAXIMUM load was determined by the control of the actuators and was not limited by either ice or blade capacity. Table 4.7 shows the ice failure and indentor control limited peaks for the tests.

2. The confinement of ice mass varied during the tests, depending on the extent of the contact area and the distance it protruded from the bucket.

3. In some tests, pronounced "sweating" of ice was visible. This is due to increased temperature of the pressurized ice in the contact zone as well as some water present in the bucket. Part of the volume of water was probably refrozen within the ice mass, especially during the slow creeping tests. This may have influenced the strength characteristics of ice in creeping tests.

4. In some tests (#14 and 15) a saturations of the blade strain signals occurred at the level of 5,000 microstrains. This was later on corrected.
5. Blade moved slightly on its foundation in the test #7.

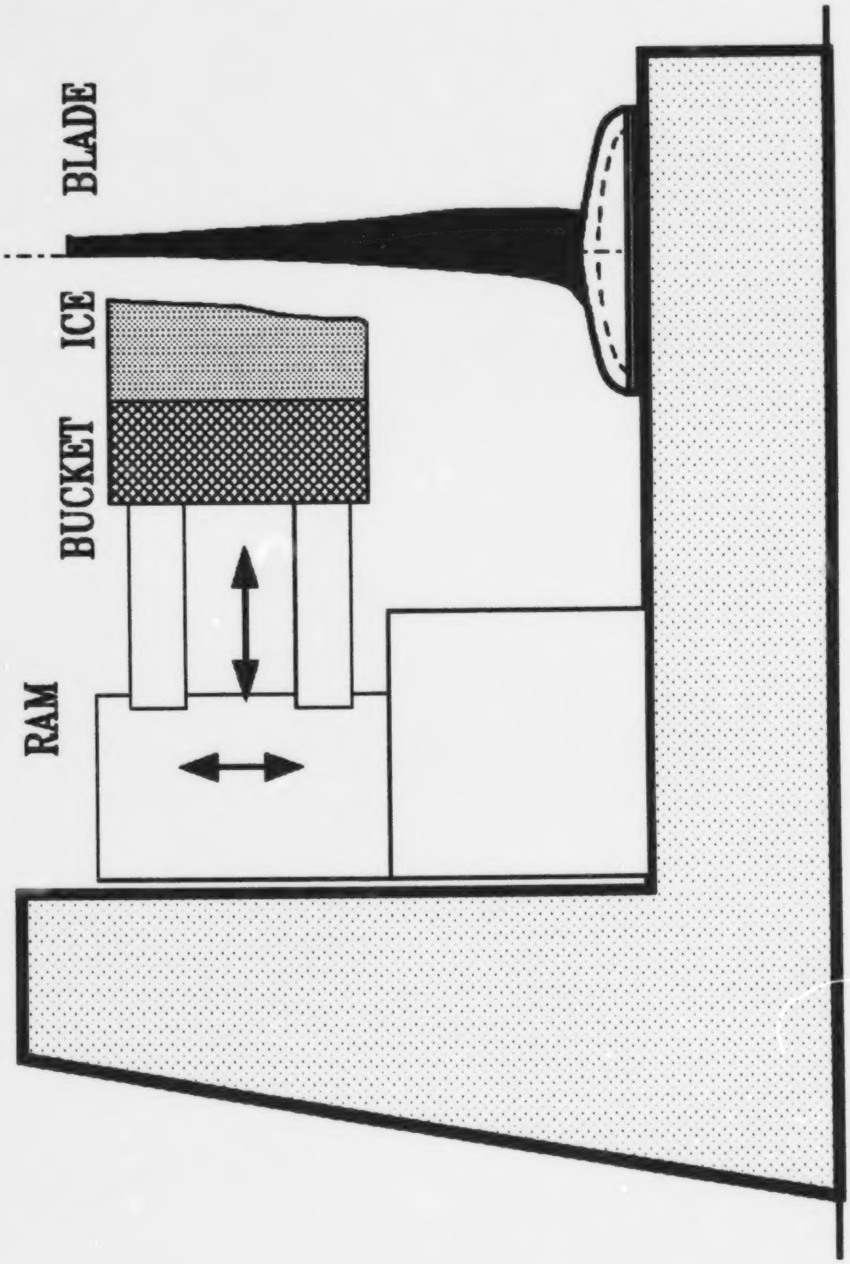
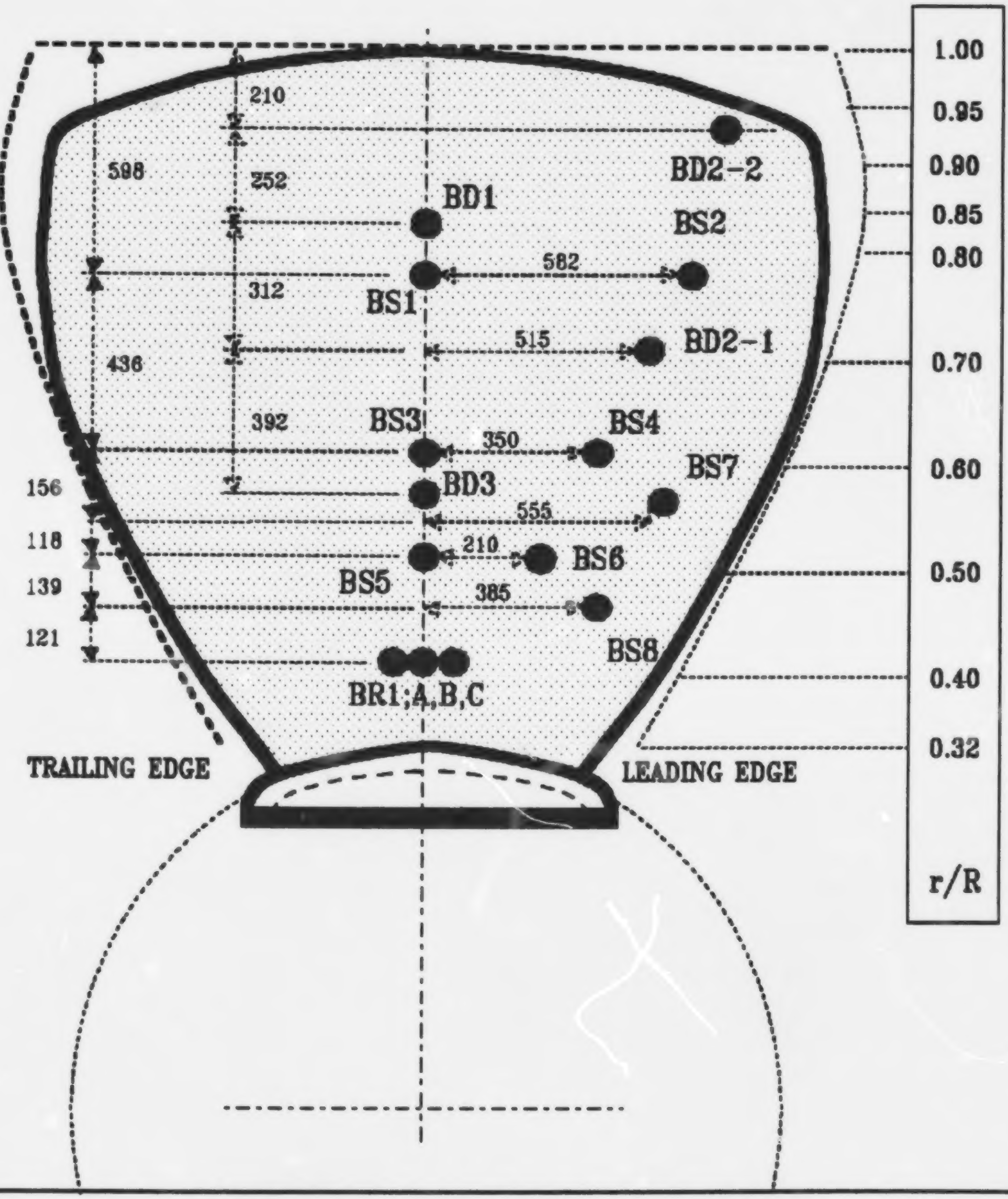

RAM
BUCKET
ICE
BLADE

FIGURE TITLE: *APPARATUS FOR KIGORIAK BLADE TEST*

PROJECT NAME: *FULL SCALE TESTS ON THE BLADE RESPONSE TO ICE*

DRAWN BY: *JER*	CHK'D BY: *VL*	SCALE: *N.T.S.*	FIGURE NR: 4.1

ARAD



1.00
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0.90
0.85
0.80
0.70
0.60
0.50
0.40
0.32
r/R
210
598
252
312
436
392
156
118
139
121
BD2-2
BD1
BS2
582
BS1
515
BD2-1
BS3
BS4
350
BS7
BD3
555
210
BS6
BS5
385
BS8
BR1;A,B,C
TRAILING EDGE
LEADING EDGE

FIGURE TITLE:	COMPRESSION SIDE INSTRUMENTATION		
PROJECT NAME:	FULL SCALE TESTS ON THE BLADE RESPONSE TO ICE		
DRAWN BY: JER/VL	**CHK'D BY:** VL	**SCALE:** NONE	**FIGURE NR:** 4.2 [illegible]

ARAD

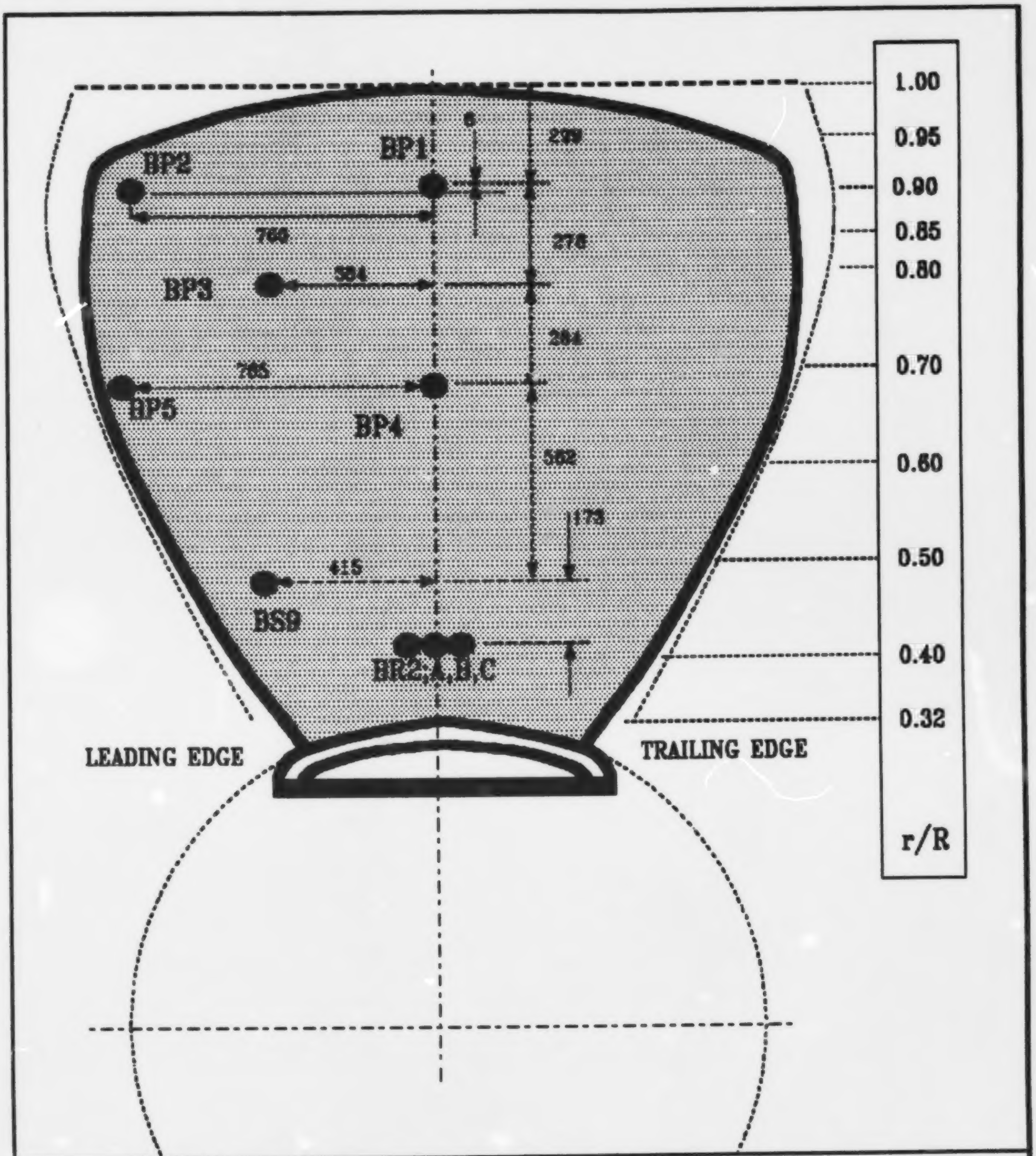

1.00
0.95
0.90
0.85
0.80
0.70
0.60
0.50
0.40
0.32
r/R
BP1
BP2
BP3
BP4
BP5
BS9
BR2;A,B,C
6
299
760
278
384
284
765
562
173
415
LEADING EDGE
TRAILING EDGE

FIGURE TITLE: TENSION SIDE INSTRUMENTATION			
PROJECT NAME: FULL SCALE TESTS ON THE BLADE RESPONSE TO ICE LOADS			
DRAWN BY: VL	CHK'D BY: VL	SCALE: NONE	FIGURE NR: 4.21

TABLE 4.1

TRANSDUCER DESIGNATION TABLE

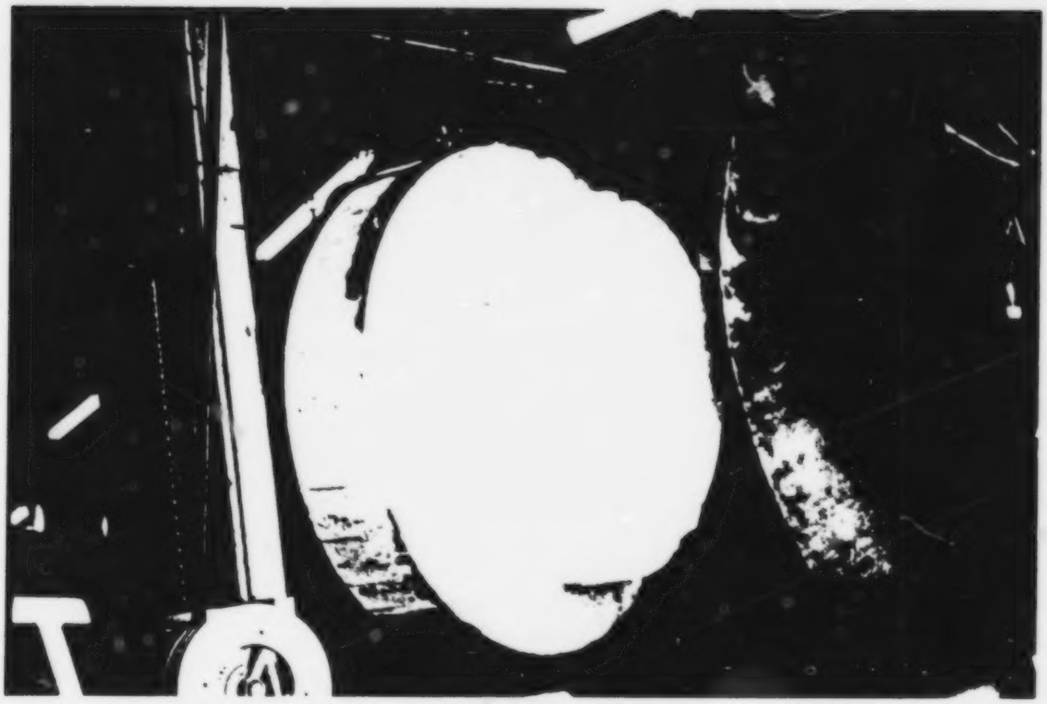
MNEMONIC	LOCATION	DESCRIPTION
AD1	Actuator 1	Actuator #1 Extensiometer
AD2	Actuator 2	Actuator #2 Extensiometer
AD3	Actuator 3	Actuator #3 Extensiometer
BD1	...Blade	Blade #1 Extensiometer
BD2	Extensiometer	Blade #2 Extensiometer
BD3	Frame...	Blade #3 Extensiometer
APE1	Actuator 1	Actuator #1 Front Pressure Gauge
APE2	Actuator 2	Actuator #2 Front Pressure Gauge
APE3	Actuator 3	Actuator #3 Front Pressure Gauge
APR1	Actuator 1	Actuator #1 Rear Pressure Gauge
APR2	Actuator 2	Actuator #2 Rear Pressure Gauge
APR3	Actuator 3	Actuator #3 Rear Pressure Gauge
BP1	...Blade	Blade Surface Pressure Cell
BP2		Blade Surface Pressure Cell
BP3	Tension	Blade Surface Pressure Cell
BP4		Blade Surface Pressure Cell
BP5	Side...	Blade Surface Pressure Cell
BR1A	...Blade	90 Degree Strain Gauge Rosette
BR1B	Compression	90 Degree Strain Gauge Rosette
BR1C	Side...	90 Degree Strain Gauge Rosette
BR2A	...Blade	90 Degree Strain Gauge Rosette
BR2B	Tension	90 Degree Strain Gauge Rosette
BR2C	Side...	90 Degree Strain Gauge Rosette
BS1	...	Single Axis Strain Gauge
BS2		Single Axis Strain Gauge
BS3		Single Axis Strain Gauge
BS4		Single Axis Strain Gauge
BS5	Blade	Single Axis Strain Gauge
BS6		Single Axis Strain Gauge
BS7		Single Axis Strain Gauge
BS8		Single Axis Strain Gauge
BS9	...	Single Axis Strain Gauge

TABLE 4.2

BLADE THICKNESS AT STRAIN GAUGES

GAUGE	THICKNESS
BS1	78
BS2	59
BS3	131
BS4	119
BS5	172
BS6	165
BS7	112
BS8	159
BR1;A,B,C	209
BS9	153
BR2;A,B,C	216

BLADE THICKNESS (MM) 90 DEGREES TO TIP OF BLADE



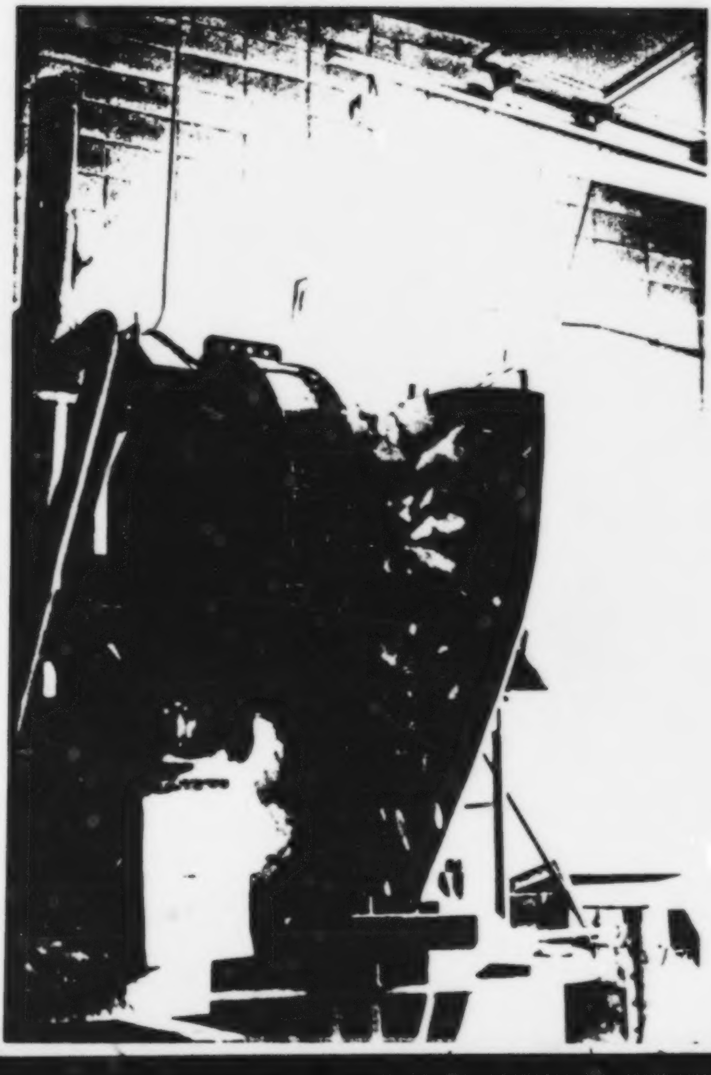
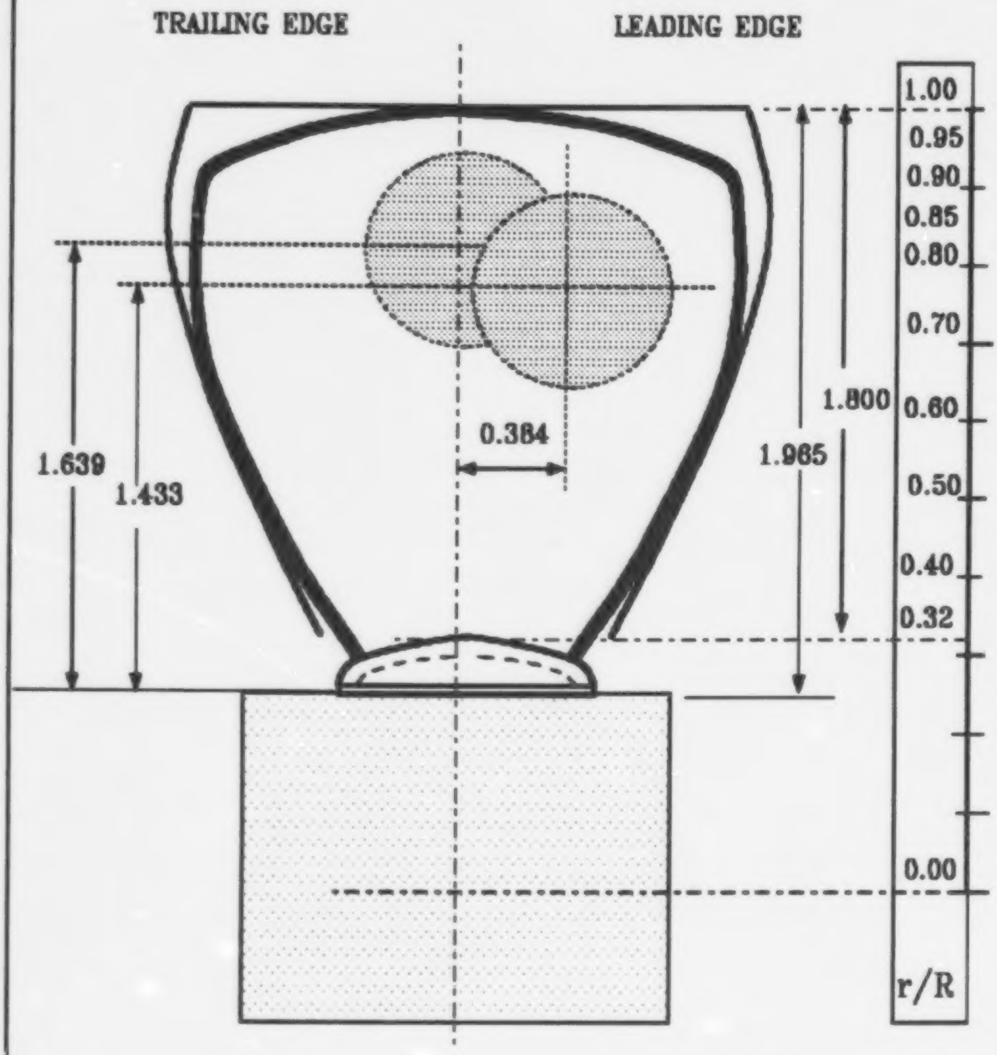


TABLE 4.4
SUMMARY OF ICE IMPACT TESTS

TEST NR	ICE TYPE	ICE COND'N	CONTACT SHAPE ICEFOOT	SURFACE AREA M^2	SPEED MM/S	MAX LOAD MN	LOCATION	COMMENTS	STRAINS
1	BLOCKS	NEW	RECTANG	1.00	91.5	0.66	CENTER	TWO LOAD PEAKS	ELASTIC
2	CRUSHED	NEW	CIRC	1.54	85.7	0.53	CENTER		ELASTIC
3	CRUSHED	USED	CIRC/WBO	1.20	83.3	0.53	CENTER		ELASTIC
4	CRUSHED	USED	POLYGON	0.68	100.0	1.03	CENTER	TWO LOAD PEAKS	ELASTIC
5	CRUSHED	NEW	TRIANG	0.60	100.0	0.37	CENTER	TWO LOAD PEAKS	ELASTIC
6	CRUSHED	USED	POLYGON	0.10	101.5	0.57	CENTER		ELASTIC
7	CRUSHED	NEW	CIRC	0.38	102.7	0.37	L.EDGE	TWO LOAD PEAKS	ELASTIC
8	CRUSHED	NEW	CIRC	0.68	100.0	0.53	L.EDGE	TWO LOAD PEAKS	ELASTIC
9	CRUSHED	NEW	CIRC	1.25	100.7	1.28	L.EDGE	TWO LOAD PEAKS	PLASTIC
10	CRUSHED	USED	CIRC	0.91	102.9	0.42	L.EDGE		ELASTIC
11	CRUSHED	USED	CIRC/RES	0.91	100.7	1.13	L.EDGE	TWO LOAD PEAKS	ELASTIC
12	CRUSHED	NEW	CIRC	1.25	100.7	1.27	L.EDGE		ELASTIC
13		ABORTED							ELASTIC
14	CRUSHED	NEW	CIRC	1.25	3.0	1.75	L.EDGE	DUCTILE	PLASTIC
15	CRUSHED	USED	POLY/RES	0.60	5.5	3.93	L.EDGE	DUCTILE	PLASTIC
16		VIBRATIONS					T.EDGE		ELASTIC
7		VIBRATIONS					CENTER		ELASTIC
18	TIMBER	NEW		0.30	103.5	2.05	L.EDGE		PLASTIC
19	TIMBER	USED	RECTANG	0.30	102.7	2.40	L.EDGE	BUCKET COLLAPSED	PLASTIC
	MAXIMUM			1.54	103.5	3.93			
	MINIMUM			0.1	3	0.37			
	AVERAGE			0.8094	86.522	1.18			

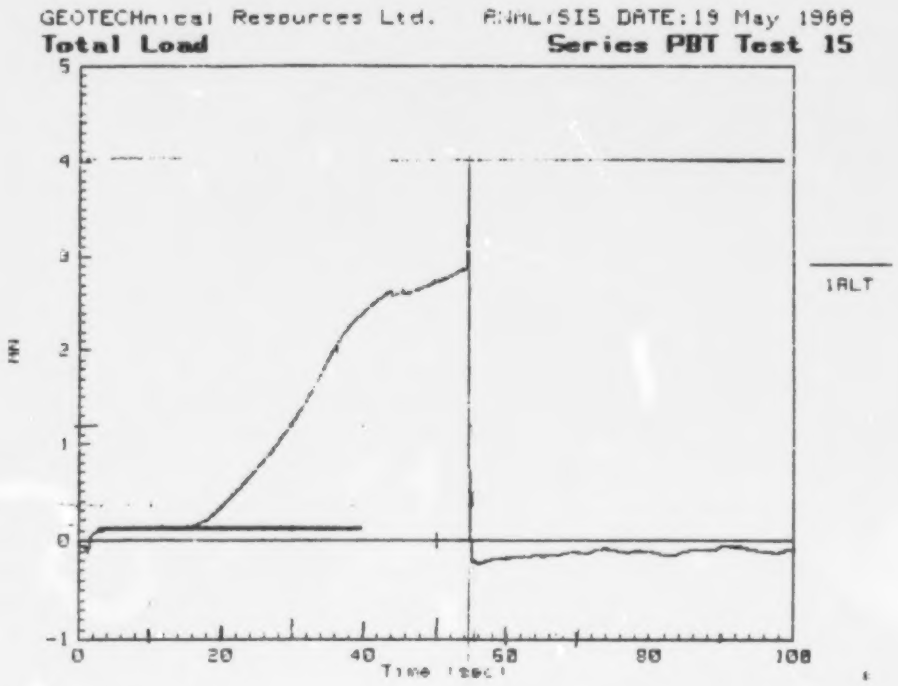

TRAILING EDGE
LEADING EDGE
1.00
0.95
0.90
0.85
0.80
0.70
0.60
0.50
0.40
0.32
0.00
r/R
1.639
1.433
0.384
1.965
1.800

BLADE CONTOUR LOOKING AFT

FIGURE TITLE: ICE CONTACT GEOMETRY DURING THE TESTS

PROJECT NAME: FULL SCALE TESTS ON THE BLADE RESPONSE TO ICE

DRAWN BY: VL	**CHK'D BY:** VL	**SCALE:** NONE	**FIGURE NR:** 4.3


GEOTECHnical Resources Ltd.
ANALYSIS DATE:19 May 1988
Total Load
Series PBT Test 15
5
4
3
2
1
0
-1
MN
0
20
40
60
80
100
Time (sec)
1ALT

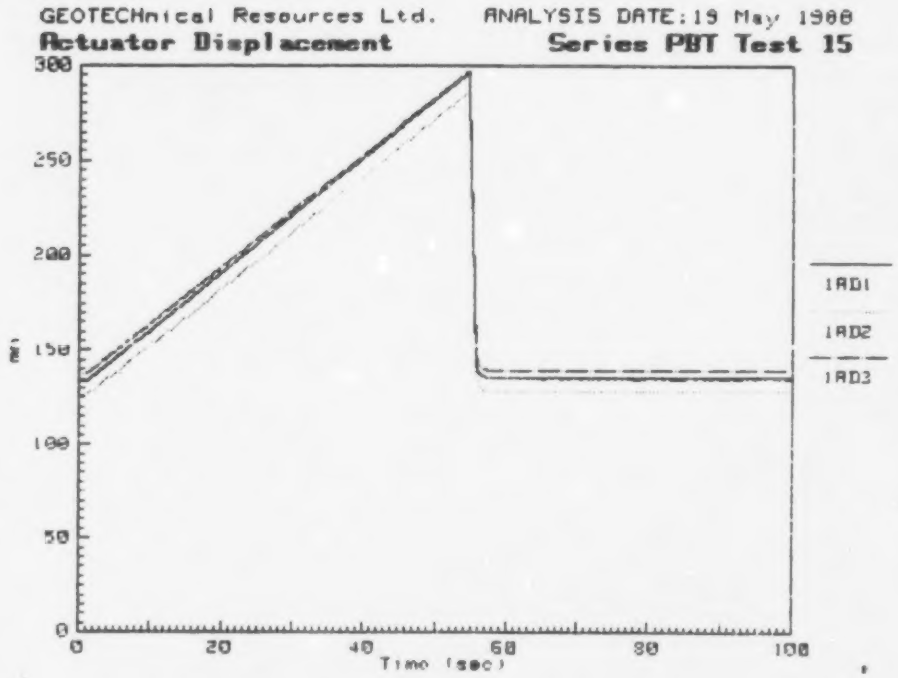

GEOTECHnical Resources Ltd.
ANALYSIS DATE:19 May 1988
Actuator Displacement
Series PBT Test 15
300
250
200
150
100
50
0
MM
0
20
40
60
80
100
Time (sec)
1AD1
1AD2
1AD3

Figure 4.4

TABLE 4.6
REFERENCE STRAIN RATES DURING THE TESTS

TEST NR	ICE TYPE	ICE COND'N	CONTACT SHAPE ICEFOOT	SURFACE AREA M^2	SPEED MM/S	STRAIN RATE 1/S	TYPE OF FAILURE
1	BLOCKS	NEW	RECTANG	1.00	91.5	0.0229	BRITTLE
2	CRUSHED	NEW	CIRC	1.54	85.7	0.0173	BRITTLE
3	CRUSHED	USED	CIRC/WBO	1.20	83.3	0.0190	BRITTLE
4	CRUSHED	USED	POLYGON	0.68	100.0	0.0303	BRITTLE
5	CRUSHED	NEW	TRIANG	0.60	100.0	0.0323	BRITTLE
6	CRUSHED	USED	POLYGON	0.10	101.5	0.0802	BRITTLE
7	CRUSHED	NEW	CIRC	0.38	102.7	0.0417	BRITTLE
8	CRUSHED	NEW	CIRC	0.68	100.0	0.0303	BRITTLE
9	CRUSHED	NEW	CIRC	1.25	100.7	0.0225	BRITTLE
10	CRUSHED	USED	CIRC	0.91	102.9	0.0270	BRITTLE
11	CRUSHED	USED	CIRC/RES	0.91	100.7	0.0264	BRITTLE
12	CRUSHED	NEW	CIRC	1.25	100.7	0.0225	BRITTLE
13			ABORTED				
14	CRUSHED	NEW	CIRC	1.25	3.0	0.0007	DUCTILE
15	CRUSHED	USED	POLY/RES	0.60	5.5	0.0018	DUCTILE
16			VIBRATIONS				
17			VIBRATIONS				
18	TIMBER	NEW		0.30	103.5	0.0472	"DUCTILE
19	TIMBER	USED	RECTANG	0.30	102.7	0.0469	"DUCTILE

TABLE 4.7
ICE/BLADE INTERACTION FORCE LIMITING MECHANISMS

TEST NR	ICE TYPE	ICE COND'N	LIMIT MECHANISMS PEAKS FIRST	LIMIT MECHANISMS PEAKS SECOND
1	BLOCKS	NEW	ICE FAILURE	INDENTOR CONTROLS
2	CRUSHED	NEW	INDENTOR	
3	CRUSHED	USED	INDENTOR	
4	CRUSHED	USED	ICE FAILURE	INDENTOR
5	CRUSHED	NEW	ICE FAILURE	INDENTOR
6	CRUSHED	USED	ICE FAILURE	INDENTOR
7	CRUSHED	NEW	ICE FAILURE	INDENTOR
8	CRUSHED	NEW	INDENTOR	
9	CRUSHED	NEW	ICE FAILURE	INDENTOR
10	CRUSHED	USED	INDENTOR	
11	CRUSHED	USED	INDENTOR	
12	CRUSHED	NEW	INDENTOR	
13		ABORTED		
14	CRUSHED	NEW	INDENTOR	
15	CRUSHED	USED	INDENTOR	
16		VIBRATIONS		
17		VIBRATIONS		
18	TIMBER	NEW	INDENTOR	
19	TIMBER	USED	INDENTOR	

5. DATA ANALYSIS

5.1 General observations regarding the ice/blade interaction process.

5.1.1. Ice/blade interaction processes

The ice/propeller interaction processes observed can be classified into the two categories:

brittle type, (#1,4,5,6,7,8,9,11,12) and
ductile type (#2,3,10,14,15,18,19)

The brittle type *is characteristic of the high speed of loading, little confinement of ice mass, and ice failure which then leads to the extrusion process.*

The ductile type *is characterized by the slow speed (but not necessarily) loading, high confinement of ice mass, no major failure of ice, and no extrusion process.*

A comparison between the two types is shown in Figure 5.1.1

For the brittle type of ice/propeller interaction process, the tests have lead to the identification of the following phases:

loading phase
ice failure phase
extrusion phase
reloading
relaxation

Test #1 is a good example of this type of failure.

The loading phase *is characterized by the development of the large contact area ("fitting" of ice) accomplished thru the local crushing and failure process of ice surface. At that point, ice strength in bulk is mobilized.*

Ice failure phase *is characterized by the load reaching a peak corresponding to the maximum strength of ice mass, followed by an a post failure unloading phase.*

In most of the tests, the post failure load fall to approximately

less than 1/2 of the peak load,

before the extrusion begun.

The extrusion process *is characterized by a large unsteady load* variation, often mixed with minor failures of ice, and the rapid growth of the load as the extrusion process terminates. The distance between the blade and confined ice mass (free space into which extrusion takes place) is a governing factor. See discussion below) During the extrusion, pronounced vibrations take place at a specific frequency. As the "gap" narrows, the load grows and reaches the limit of the actuators' capacity.

The relaxation phase is characterized by the slow drop of the loading on the blade and return of the blade towards its original position

The ductile type of ice/propeller interaction process has three phases:

loading
failure, and
relaxation

Loading phase has a characteristic smooth and rapid growth of the concave shape. No major failures of ice take place at this time.

Failure phase is achieved after the certain load level is reached and the internal and local failures within the ice mass occur. Sounds of internal cracking accompany this phase. The slope of the load changes, as some local areas loose the pressure on the blade. The peak load is reached when the actuators displacement is the highest.

Relaxation phase follows after the actuators are withdrawn.

5.1.2 Ice failure load/peak blade loading

The first peak characteristic of ice failure is lower than the post failure peak (except for the tests 11 and 12) at the end of the extrusion process.

The post failure load drop is,usually, less than 1/2 of the peak value. Table 5.1.1 gives the values of the peak load and the pre - extrusion value of the load drop for the tests. The following observations can be made:

Average drop ratio (post failure load/Max load) was to about 0.3 of the peak value. The maximum was 0.55.

For the secondary failure peak, the ratio was higher, 0.4 on the average, and 0.61 maximum. This is probably due to the fact that the contact area in the second failure phase was larger.

Figure 5.1.2 shows the correlation between the ice failure load and the peak blade load, for eleven tests. A strong linear correlation is apparent.

Both loads are linked to the ice strength and the degree of its confinement.

5.1.3 Rate of loading/speed of advance

Figure 5.1.3 shows the correlation between the speed of advance, in mm/s and the rate of loading (measured as a peak force /distance travelled before the peak is reached), in MN/m. The following observations are made:

1. *Rate of loading is inversely proportional to the speed of advance.*
2. *There is no difference between the speed of loading for weak ice and timber.*

5.1.4 Ice extrusion process

Figure 5.1.4 shows the trace of the load in the extrusion process.

The extrusion process is characterized by the sudden drop of the pressure after the failure and then gradual build up of the pressure as the thickness of the extruded layer decreases to zero. This phase can be described as squeezing of a viscous layer out between the two rigid boundaries. The equation governing this phase is, (for the two dimensional case) after the Reference 3:

$$F = eta * V * (l/h)^{3} \qquad 5.1.1$$

where:

F   is the force on the indentor (N),
eta is the viscosity of the crushed layer (kg/s),
V   is the velocity of advance of the indentor (m/s),
l   is the half width of the indentor (m), and
h   is the thickness of the viscous matter between the two rigid boundaries (m)

That is, ***the force is inversely proportional to the thickness of*** *the crushed layer cubed.*

In our case, the width of the contact area and the viscosity and thickness of it are interdependent.

As there is less and less of the crushed material to extrude, the thickness of the layer decreases and the pressure builds up until the bulk material fails again, supplying a new crushed layer for *extrusion. The process repeats itself. Often the pronounced vibrations take place between the indentor and the structure.*

Table 5.1.2 shows the exponents of the thickness of the layer computed for some extrusion tests:

TABLE 5.1.2

Thickness exponent for extrusion tests

test	exponent
1	3.7
4	3.3
5	3.0
6	1.3
7	2.3
average	2.7
min	1.3
max	3.7

Figure 5.1.1.

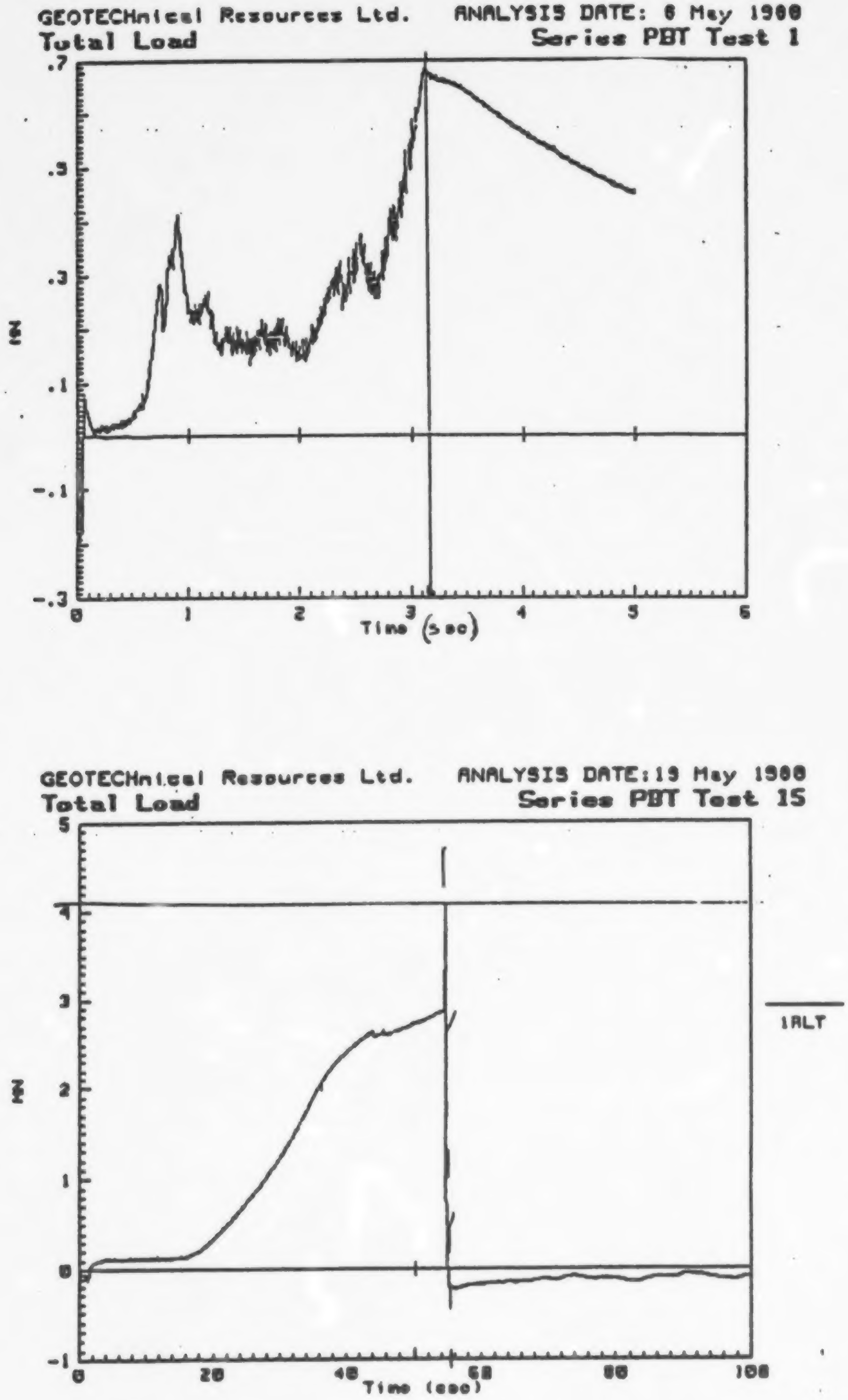
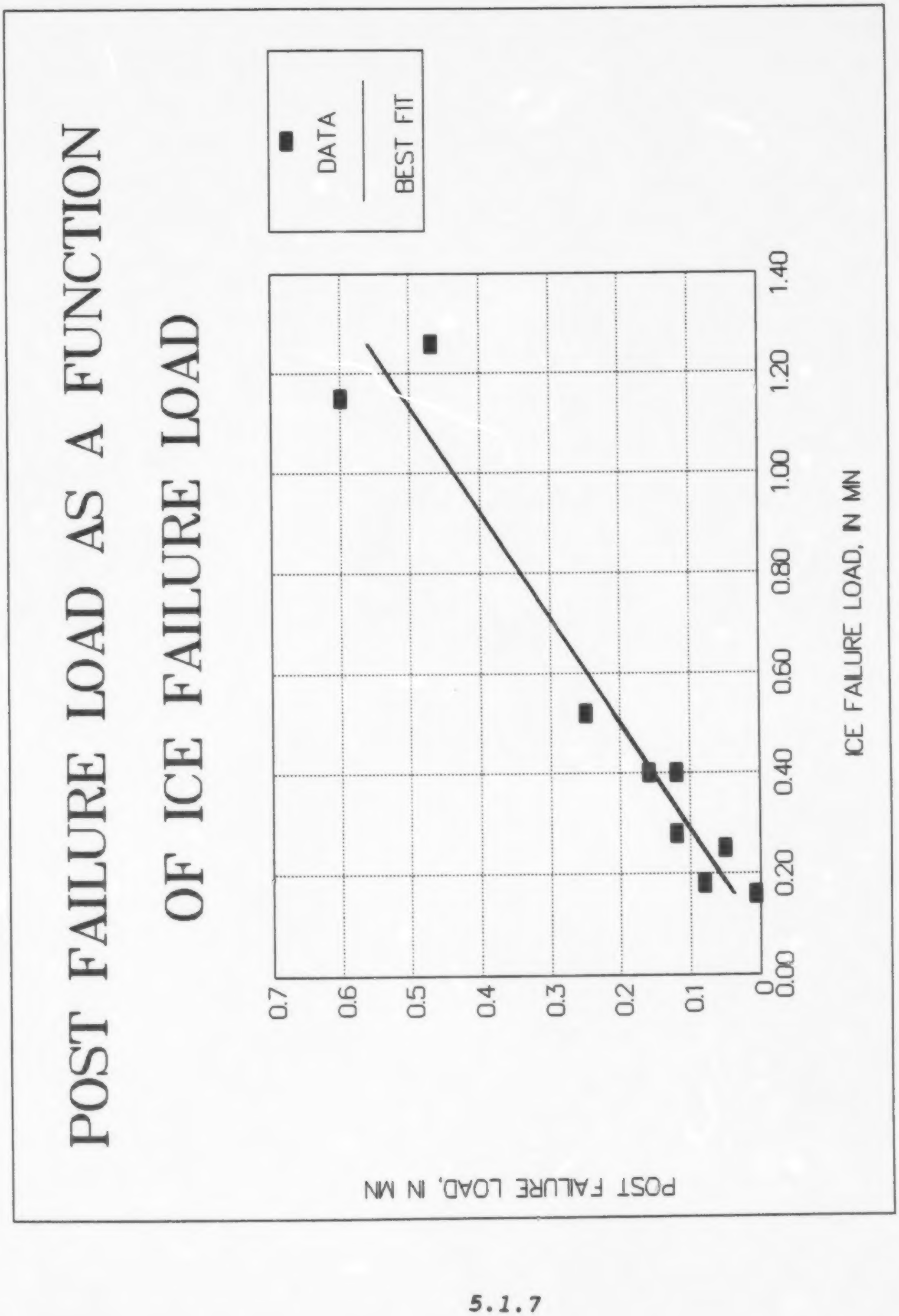

GEOTECHnical Resources Ltd.
ANALYSIS DATE: 6 May 1988
Total Load
Series PBT Test 1
.7
.5
.3
.1
-.1
-.3
MN
0
1
2
3
4
5
6
Time (sec)
GEOTECHnical Resources Ltd.
ANALYSIS DATE:19 May 1988
Total Load
Series PBT Test 15
5
4
3
2
1
0
-1
MN
0
20
40
60
80
100
Time (sec)
1ALT

TABLE 5.1.1.

ICE FAILURE LOADS AND POST FAILURE LOADS

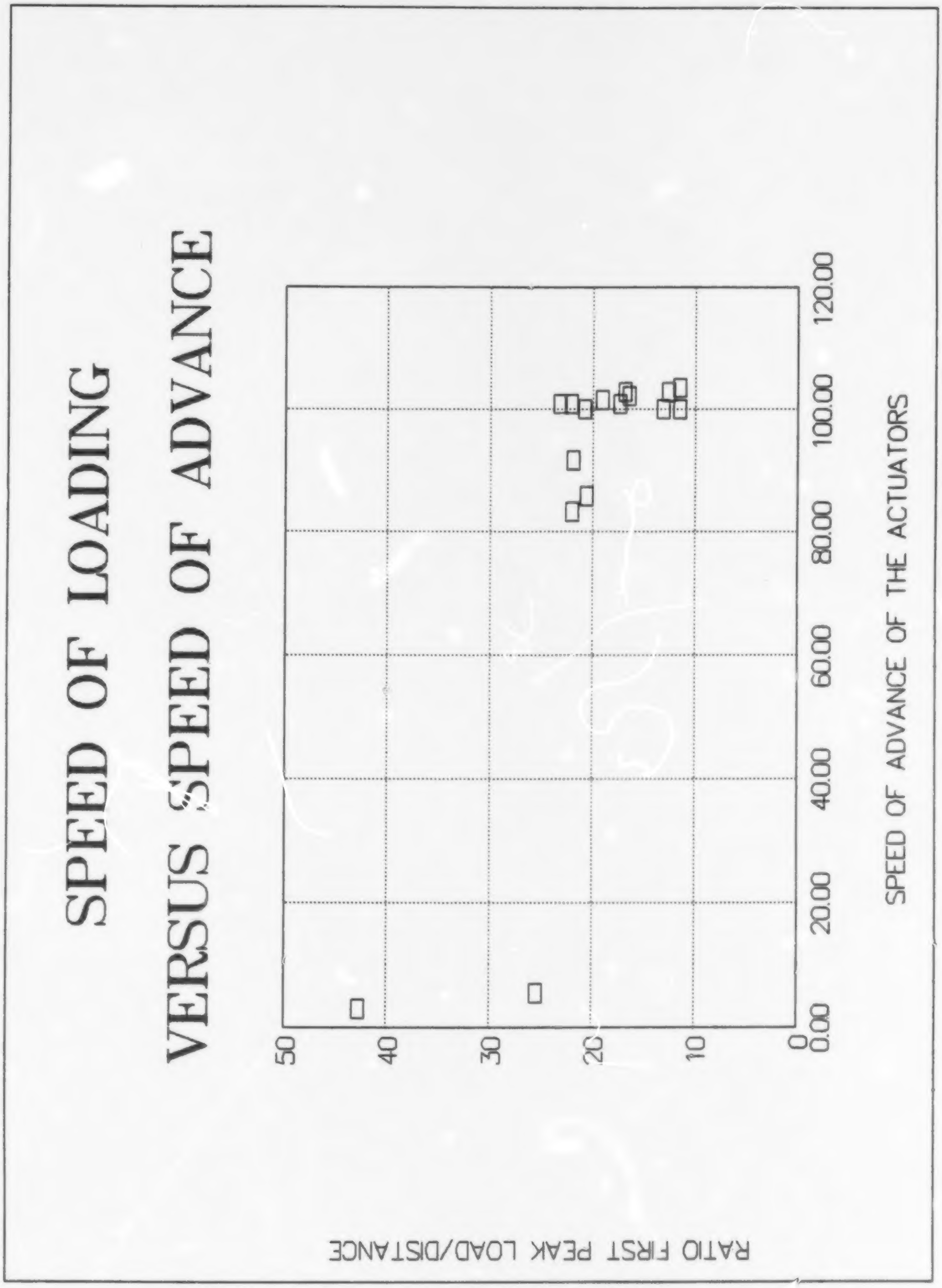
TEST NR	PEAK #1			PEAK #2			MAX LOAD, MN	RATIO PEAK1/MAX
	MAX	POST	RATIO	MAX	POST	RATIO		
1	0.400	0.160	0.400				0.660	0.606
4	0.250	0.050	0.200				1.030	0.243
5	0.158	0.000	0.000				0.370	0.427
6	0.280	0.120	0.429	0.570	0.350	0.614	0.570	0.491
7	0.180	0.080	0.444	0.370	0.180	0.486	0.370	0.486
8	0.520	0.250	0.481				0.530	0.981
9	0.400	0.120	0.300	1.280	0.150	0.117	1.280	0.313
11	1.150	0.600	0.522				1.130	1.018
12	1.260	0.470	0.373				1.270	0.992
MIN	0.158	0.000	0.000	0.370	0.150	0.117	0.370	0.243
AVGE	0.511	0.206	0.296	0.740	0.227	0.406	0.801	0.617
MAX	1.260	0.600	0.522	1.280	0.350	0.614	1.280	1.018

Figure 5.1.2.



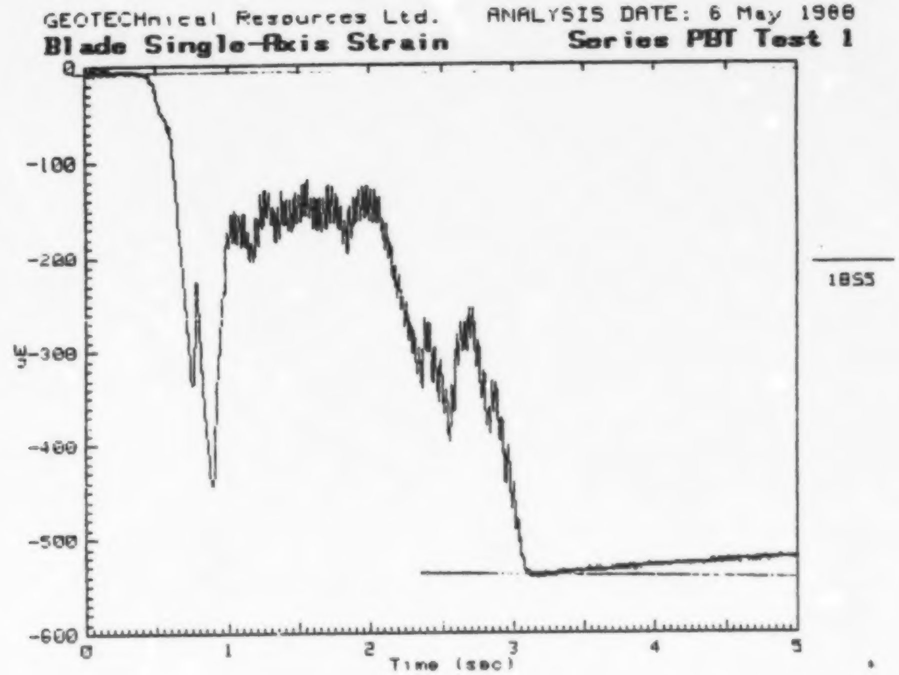
POST FAILURE LOAD AS A FUNCTION OF ICE FAILURE LOAD

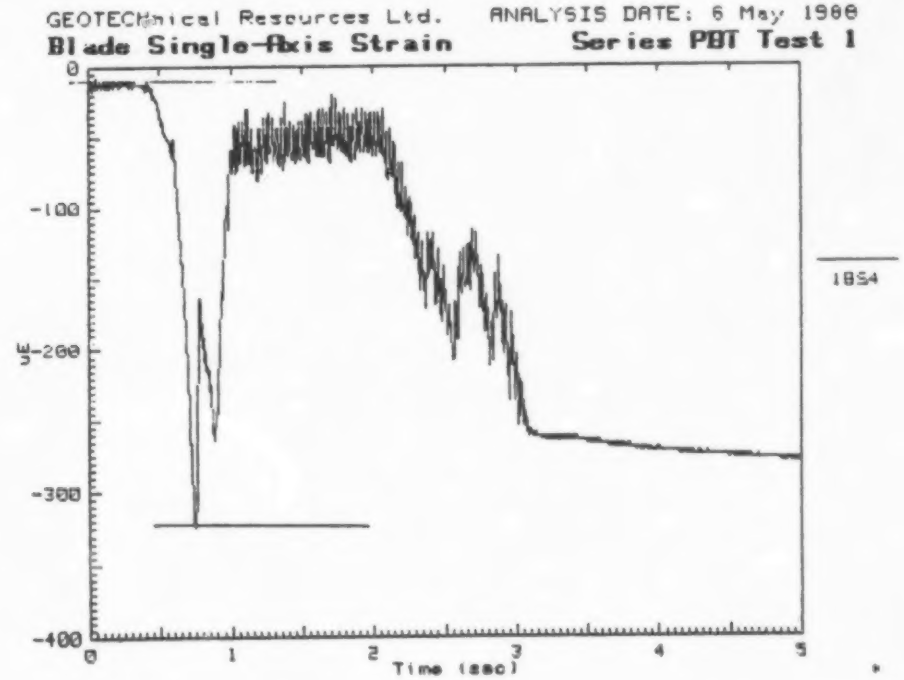
Figure 5.1.3.

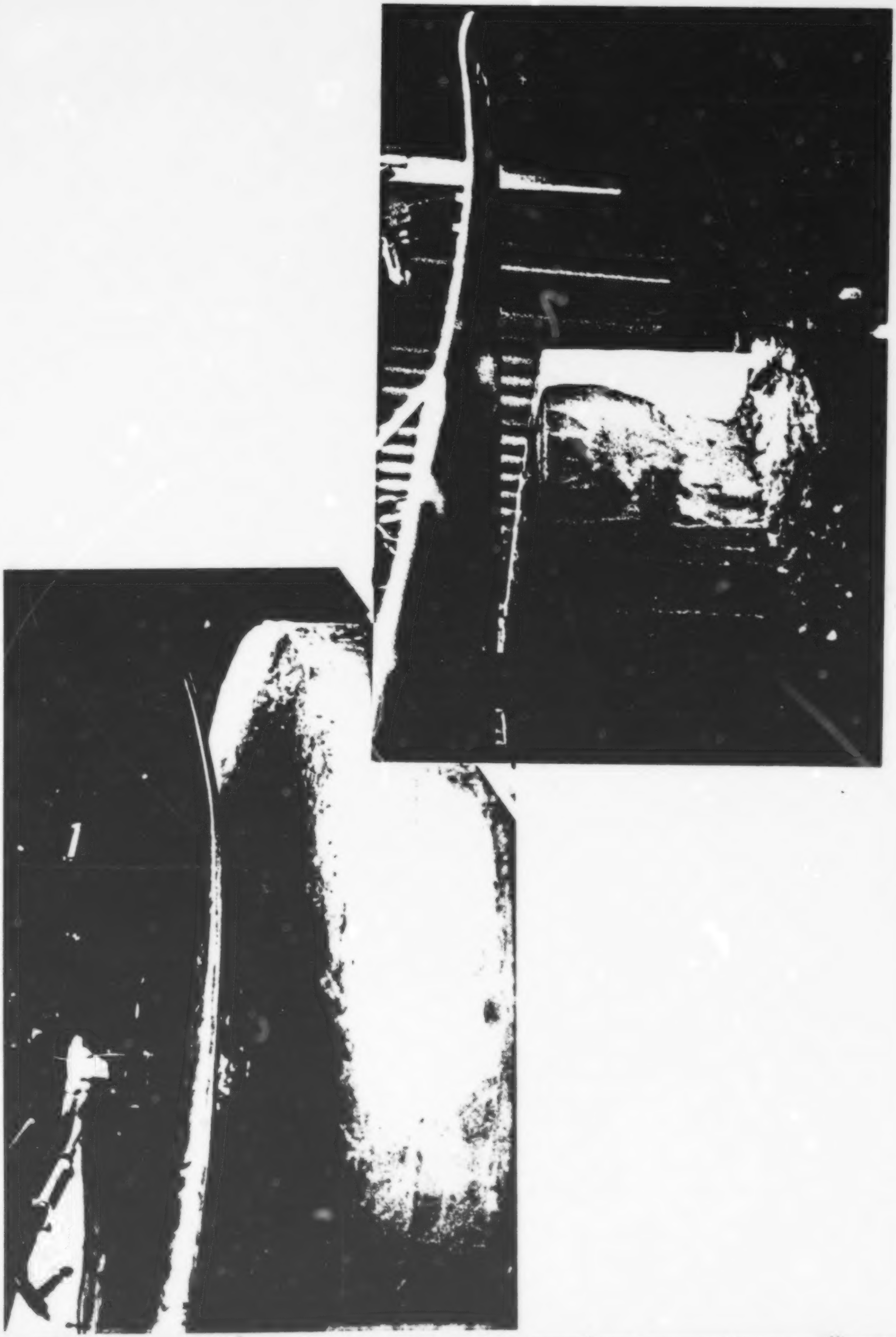


SPEED OF LOADING VERSUS SPEED OF ADVANCE

Figure 5.1.4.


GEOTECHnical Resources Ltd.
ANALYSIS DATE: 6 May 1988
Blade Single-Axis Strain
Series PBT Test 1
0
-100
-200
-300
-400
-500
-600
uE
0
1
2
3
4
5
Time (sec)
1855


GEOTECHnical Resources Ltd.
ANALYSIS DATE: 6 May 1988
Blade Single-Axis Strain
Series PBT Test 1
0
-100
-200
-300
-400
uE
0
1
2
3
4
5
Time (sec)
1854


1

5.2 Calculations of the effective location of load application.

Method

The geometry of the actuators is shown in Figure 5.2.1. A symmetrical triangular shape is apparent, having a height of 0.813 m and the base width of 0.960 m. The method of calculating the peak load location was as follows.

The vertical location of the effective peak load above the triangle's base:

$$VCG = 0.813 * L3 \; / \; \text{Total load} \qquad \ldots\ldots 5.1$$

where L3 is the load developed by actuator #3.

The horizontal location of the peak load was calculated as follows:

$$LCG = 0.480*(L2-L1)/\text{Total load} \qquad \ldots\ldots 5.2$$

where L2 and L1 are the loads developed by actuators #2 and #1, respectively. The positive sign corresponds to the right side of the triangle's axis, looking into the actuators.

The position of the peak load on the blade was calculated adding the locations within the triangle to the location of the triangle reference point:

Tests 1 to 6

$$BVCG = VCG + 1.122 \qquad \ldots\ldots 5.4$$
$$BLCG = LCG + 0.035 \qquad \ldots\ldots 5.5$$

Tests 7 to 19

$$BVCG = VCG + 1.328 \qquad \ldots\ldots 5.6$$
$$BLCG = LCG + 0.397 \qquad \ldots\ldots 5.7$$

Results

The results of the calculations **for the peak forces** are presented in Table 5.2.1. For some tests data was not available. The following values are computed:

> vertical and horizontal position of the load, in absolute and relative terms within the triangle, and the absolute position of the load on the blade.

Statistics of the loads and the loci is contained at the bottom of the table.

The following observations can be made:

- Actuator #3 (the top one) experienced both the highest (1.91 MN) and the highest average (0.47 MN)loads.

- Actuator #2 (right hand side) showed the most consistent loading, as both the standard deviation from the mean and variance were the lowest.

- The average calculated location of the peak loads for all the tests is:

  VCG(all) = 0.320 m,
  LCG(all) = 0.130 m.

  That is, the average center of the loads for all the tests lies very near the geometric center of the actuators' triangle (0.27m,0.00m).

- The maximum vertical location of the maximum load was 0,55m, while the horizontal one was 0.42 m towards the leading edge. These values are approximately 1/2 of the actuator's triangle dimensions.

Figure 5.2.2 shows the location of the center of the maximum force within the triangle for the tests 1 to 6 and Figure 5.2.3 for the tests 7 to 19, as functions of the magnitude of the loads.

The following observations can be made:

Vertical location of the load does not change with its magnitude within the triangle, and rests about the 1/2 triangle's height. This is contrary to the expectation of the load center being at the center of gravity of the triangle (0.271m). This is due to the facts that:

> for these low loads, the blade did not deformed significantly in the fore and aft direction, and
> the ice block was shaped to fit the blade surface.

Horizontal location of the load does change from the right hand offset to the near the center on the left hand side. This can be explained as follows:

> blade is deforming more in the horizontal direction than the vertical one.
> as the blade deforms, the stiffer centerline " backbone" attracts more load than the weaker edge.

For all the tests, the Figure 5.2.4 shows the relative locations of the force vector in the actuator's triangle. More pronounced horizontal spread than the vertical one is due to the fact that the horizontal application of the load was shifted significantly form the center of the blade to the leading edge, while the vertical was not.

Figures 5.2.5 and 5.2.6 show the distribution of the maximum load location on the blade. On the average, the vertical location on the blade was:

1.56 m

while the horizontal was:

0.37 m

These locations correspond closely to those observed during the full scale trials (reference 4).

Figure 5.2.7 shows the change of the load and figure 5.2.8 change of load location within the actuators' triangle during the test #15 (maximum load).

The following observations can be made:

Vertical location of the load is near the geometric center of the triangle for the low loads. As the load grows, it drops down, where the blade offers more resistance. As the load grows further, the center of load application moves away towards the midheight of the triangle, due to the flaking taking place at the bottom of the load area.

This flaking and readjustment of the contact area is seen in the video movie as well as in the traces of the loads from the actuators 1 and 2 which did not grow up past the 40sec, while the load on the actuator 3 grew rapidly.

The horizontal location of the load drifts from the right side hand of the triangle to the left hand side, where the blade offers more resistance. Again, some fluctuation of the locus is due to the change of the contact area due to the edge flaking.

Figure 5.2.9 shows the plot of the load of one actuator versus the other, during the test #1. Uneven and changing distribution of the load between the three actuators is apparent.

Conclusions

1. Contact area and the consequent point of the load application display **self adjusting property**, that is, the highly loaded off-center area are crushed and removed form the contact zone, forcing the load to a more central position.
2. Center part of the blade attracts more load than the edge, hence the point of application of the load gravitates towards the centerline of the blade.
3. Vertical shift in the location of the load vector is smaller than the horizontal one, due to the blade stiffness distribution.
4. Point of application of the loads correspond closely to the ones observed in the full scale trials.
5. The movement of the point of application of the load is small in comparison to the blade and bucket dimensions.
6. The point of application of the load during the interaction changes continuously.

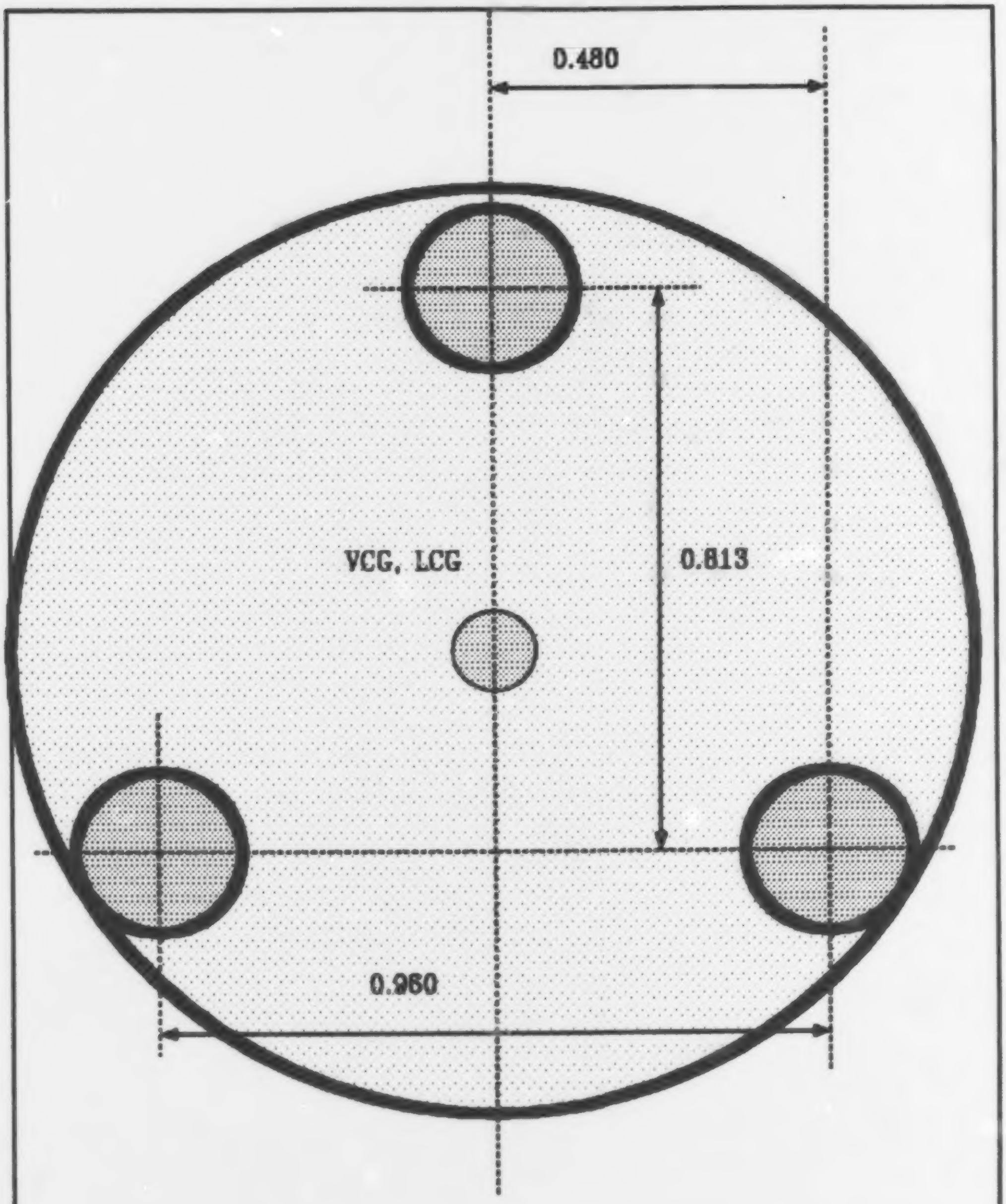

0.480
VCG, LCG
0.813
0.960

FIGURE TITLE: GEOMETRY OF THE ACTUATOR'S TRIANGLE			
PROJECT NAME: FULL SCALE TESTS ON THE BLADE RESPONSE TO ICE			
DRAWN BY: VL	CHK'D BY: VL	SCALE: NONE	FIGURE NR: 5.2.1

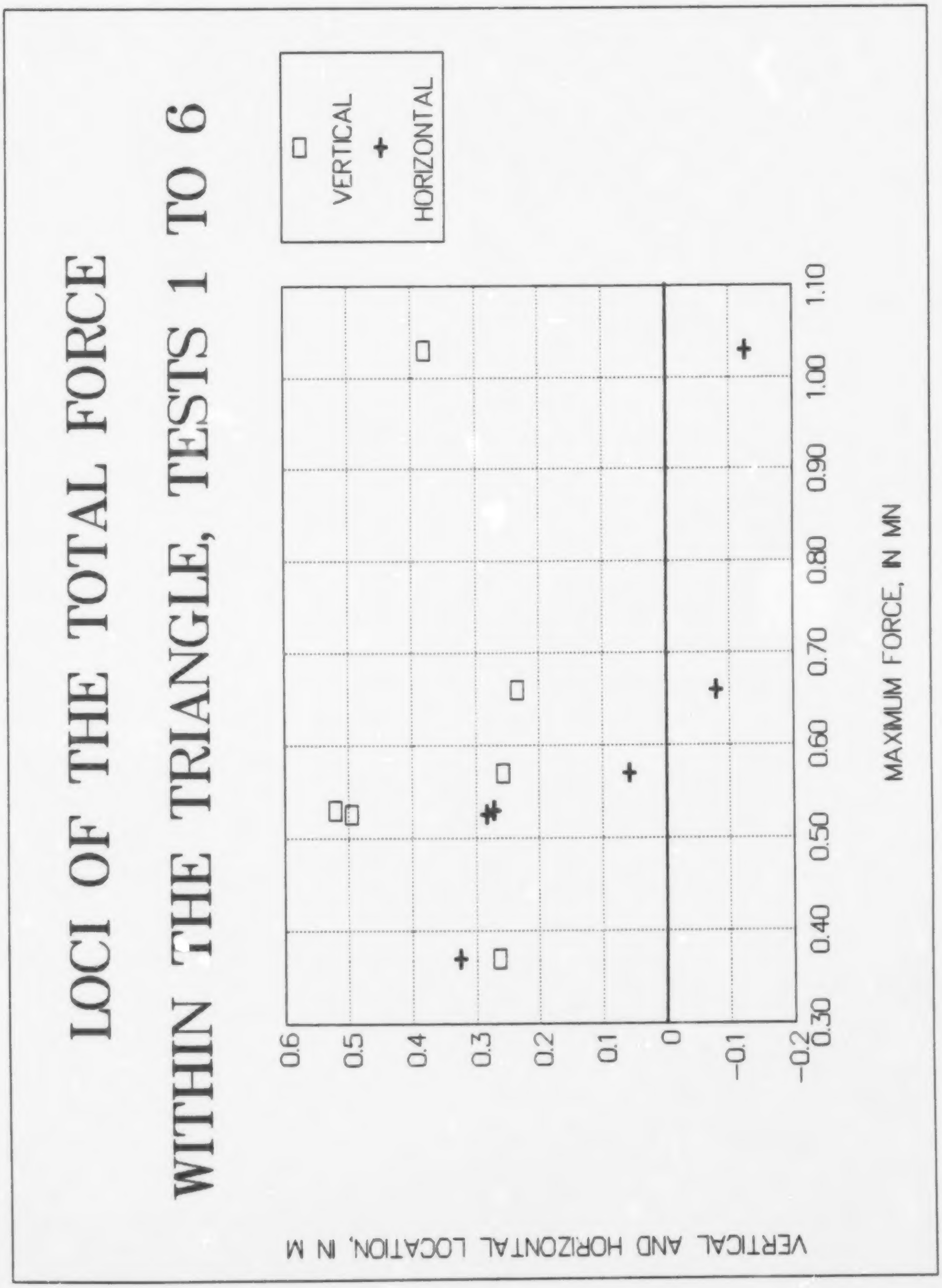
ARAD

TABLE 5.2.1.

LOCATIONS OF THE CENTER OF EFFORT
FOR ALL TESTS

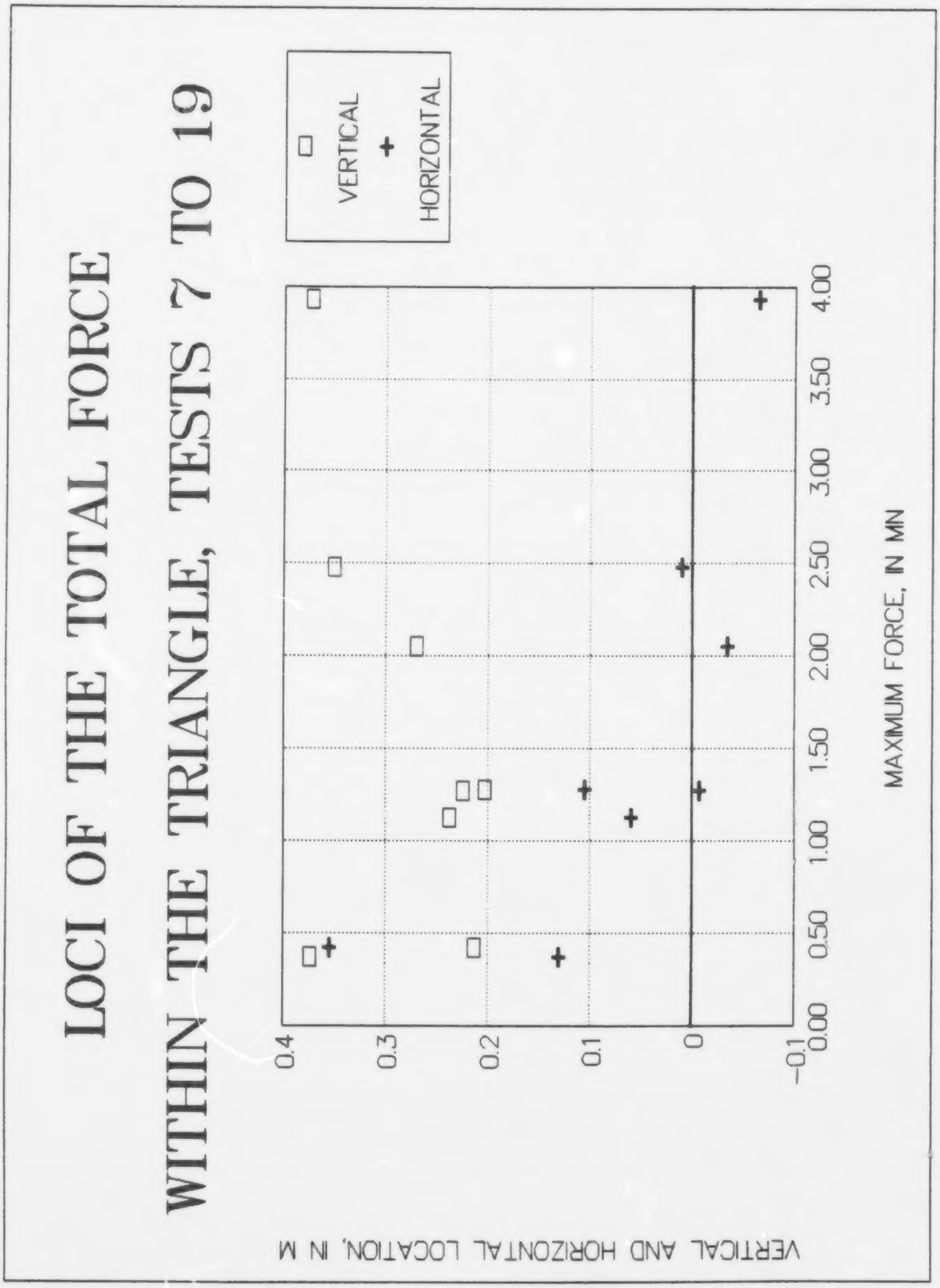
TEST	MAXIMUM LOADS				POSITION OF		AGAINST		RELATIVE	
NR	TOTAL	ACT1	ACT2	ACT3	VECTOR,	IN M	THE BLADE		TO THE ACT'R	
	MEGANEWTONS				VERT	HORIZ	BASE	CENTER	Z	X
1	0.66	0.29	0.18	0.19	0.23	(0.08)	1.36	(0.04)	0.29	(0.17)
2	0.53	(0.05)	0.26	0.32	0.50	0.28	1.62	0.32	0.61	0.59
3	0.53	(0.06)	0.24	0.34	0.52	0.27	1.64	0.31	0.64	0.57
4	1.03	0.41	0.14	0.48	0.38	(0.13)	1.50	(0.09)	0.47	(0.26)
5	0.37	0.00	0.25	0.12	0.26	0.32	1.39	0.36	0.32	0.68
6	0.57	0.16	0.23	0.18	0.26	0.06	1.38	0.09	0.32	0.12
7	0.37	0.05	0.15	0.17	0.37	0.13	1.70	0.53	0.46	0.27
8	0.53									
9	1.28	0.34	0.62	0.32	0.20	0.10	1.53	0.50	0.25	0.22
10	0.42	0.00	0.31	0.11	0.21	0.35	1.54	0.75	0.26	0.74
11	1.13	0.33	0.47	0.33	0.24	0.06	1.57	0.46	0.29	0.12
12	1.27	0.47	0.45	0.35	0.22	(0.01)	1.55	0.39	0.28	(0.02)
13										
14	1.75									
15	3.93	1.33	0.80	1.80	0.37	(0.06)	1.70	0.33	0.46	(0.13)
16										
17										
18	2.05	0.76	0.61	0.68	0.27	(0.04)	1.60	0.36	0.33	(0.07)
19	2.48	0.68	0.73	1.07	0.35	0.01	1.68	0.41	0.43	0.02
MAX	3.93	1.33	0.80	1.80	0.52	0.35	1.70	0.75	0.64	0.74
MIN	0.37	(0.06)	0.14	0.11	0.20	(0.13)	1.36	(0.09)	0.25	(0.26)
AVGE	1.18	0.34	0.39	0.46	0.31	0.09	1.55	0.33	0.39	0.19
STDEV	0.94	0.37	0.22	0.45	0.10	0.15	0.11	0.21	0.12	0.32
VAR	0.89	0.14	0.05	0.20	0.01	0.02	0.01	0.05	0.02	0.10

Figure 5.2.2.



LOCI OF THE TOTAL FORCE WITHIN THE TRIANGLE, TESTS 1 TO 6

Figure 5.2.3.



LOCI OF THE TOTAL FORCE WITHIN THE TRIANGLE, TESTS 7 TO 19

Figure 5.2.4.

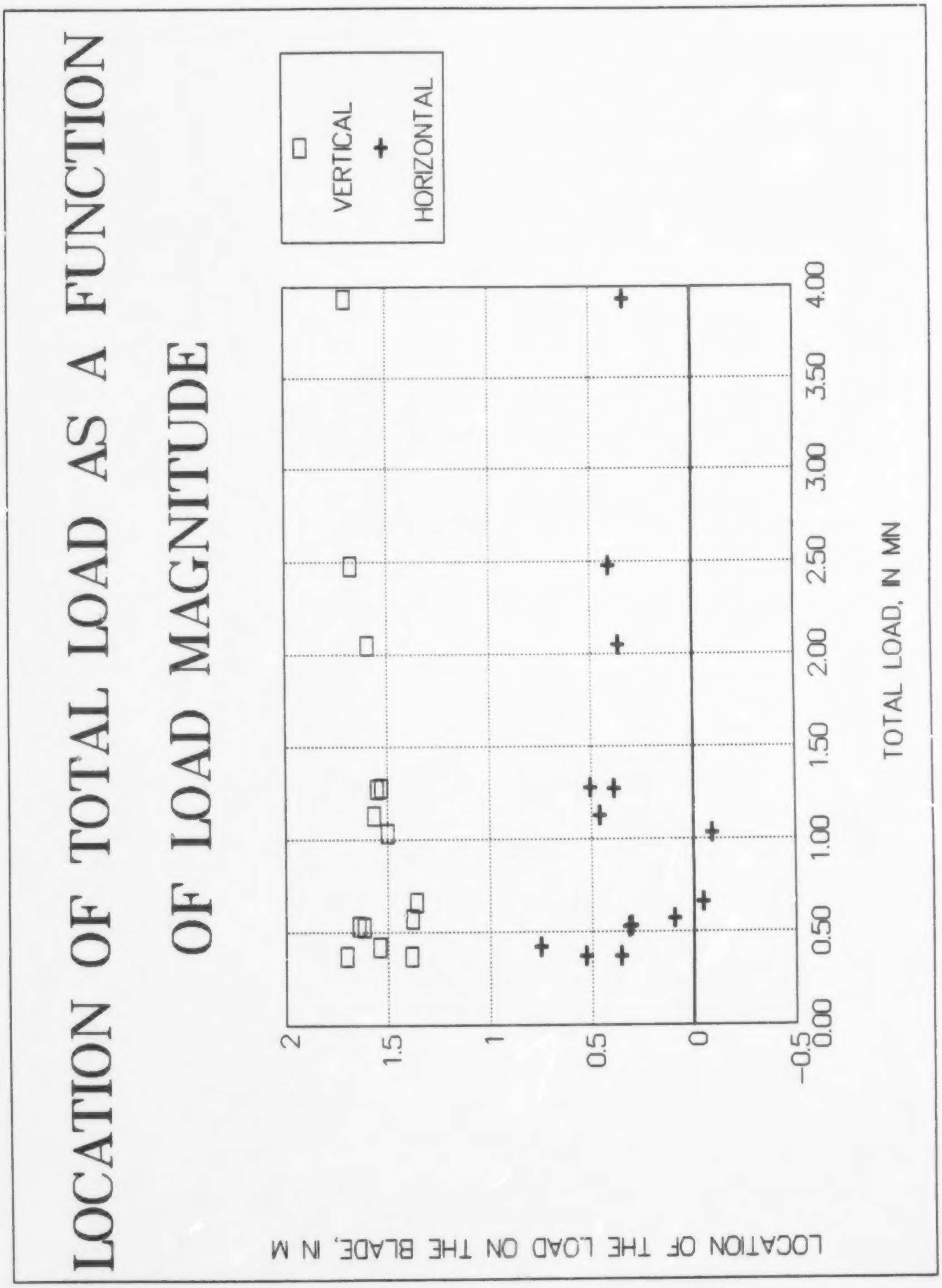
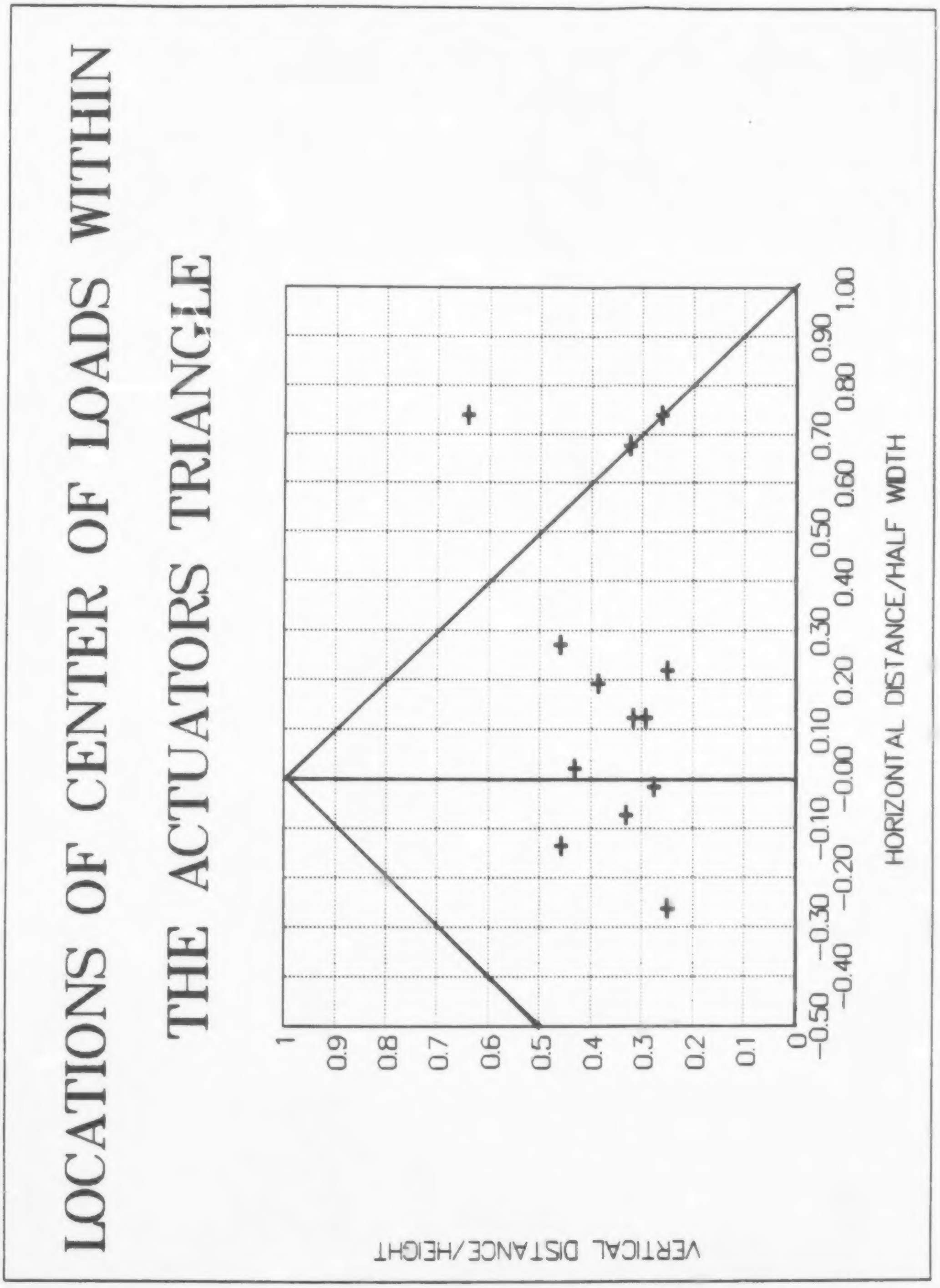

LOCATION OF TOTAL LOAD AS A FUNCTION OF LOAD MAGNITUDE
□ VERTICAL
+ HORIZONTAL
LOCATION OF THE LOAD ON THE BLADE, IN M
TOTAL LOAD, IN MN
2
1.5
1
0.5
0
-0.5
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00

Figure 5.2.5.


LOCATIONS OF CENTER OF LOADS WITHIN
THE ACTUATORS TRIANGLE
VERTICAL DISTANCE/HEIGHT
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
HORIZONTAL DISTANCE/HALF WIDTH
-0.50
-0.40
-0.30
-0.20
-0.10
-0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00

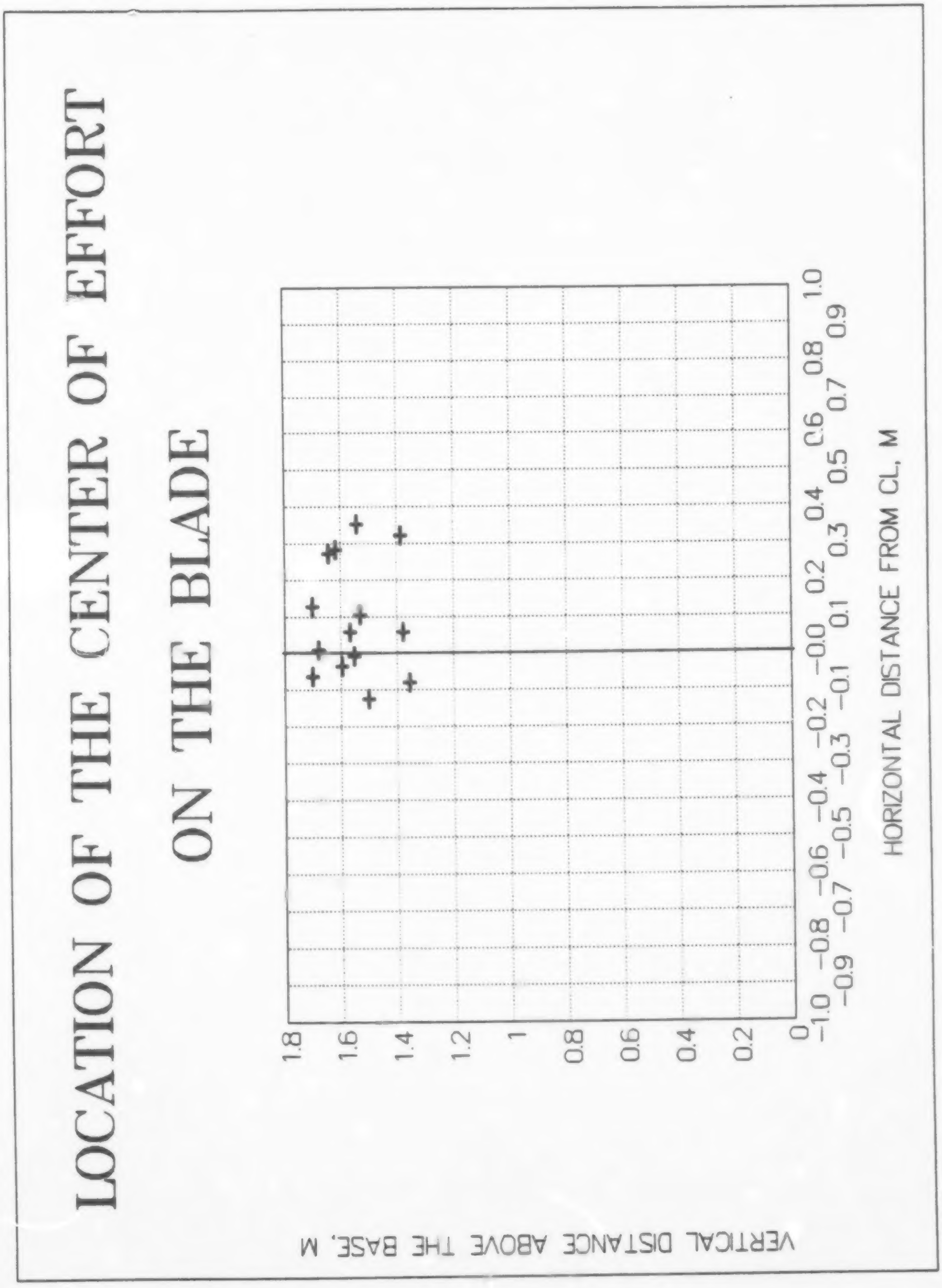
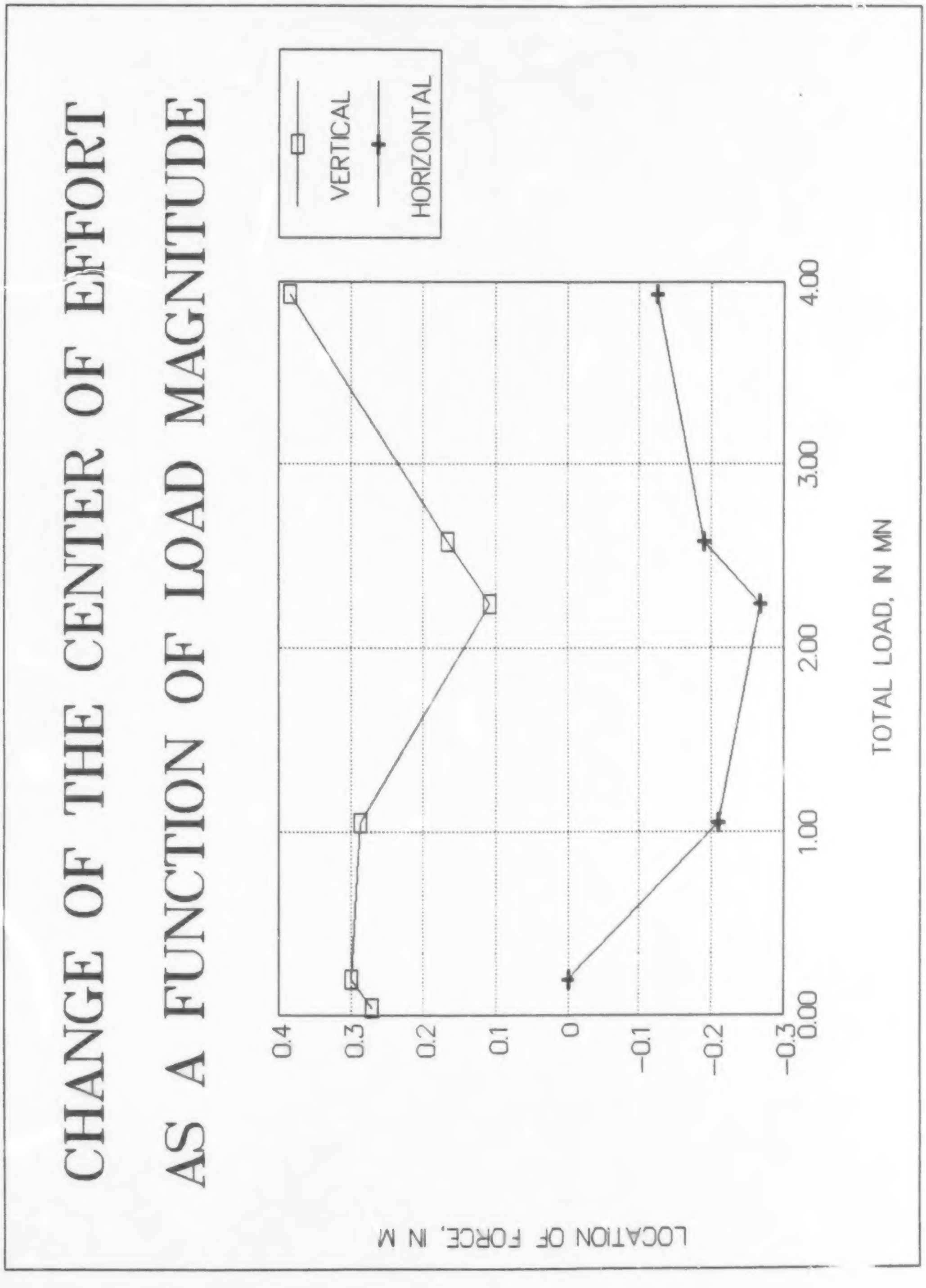
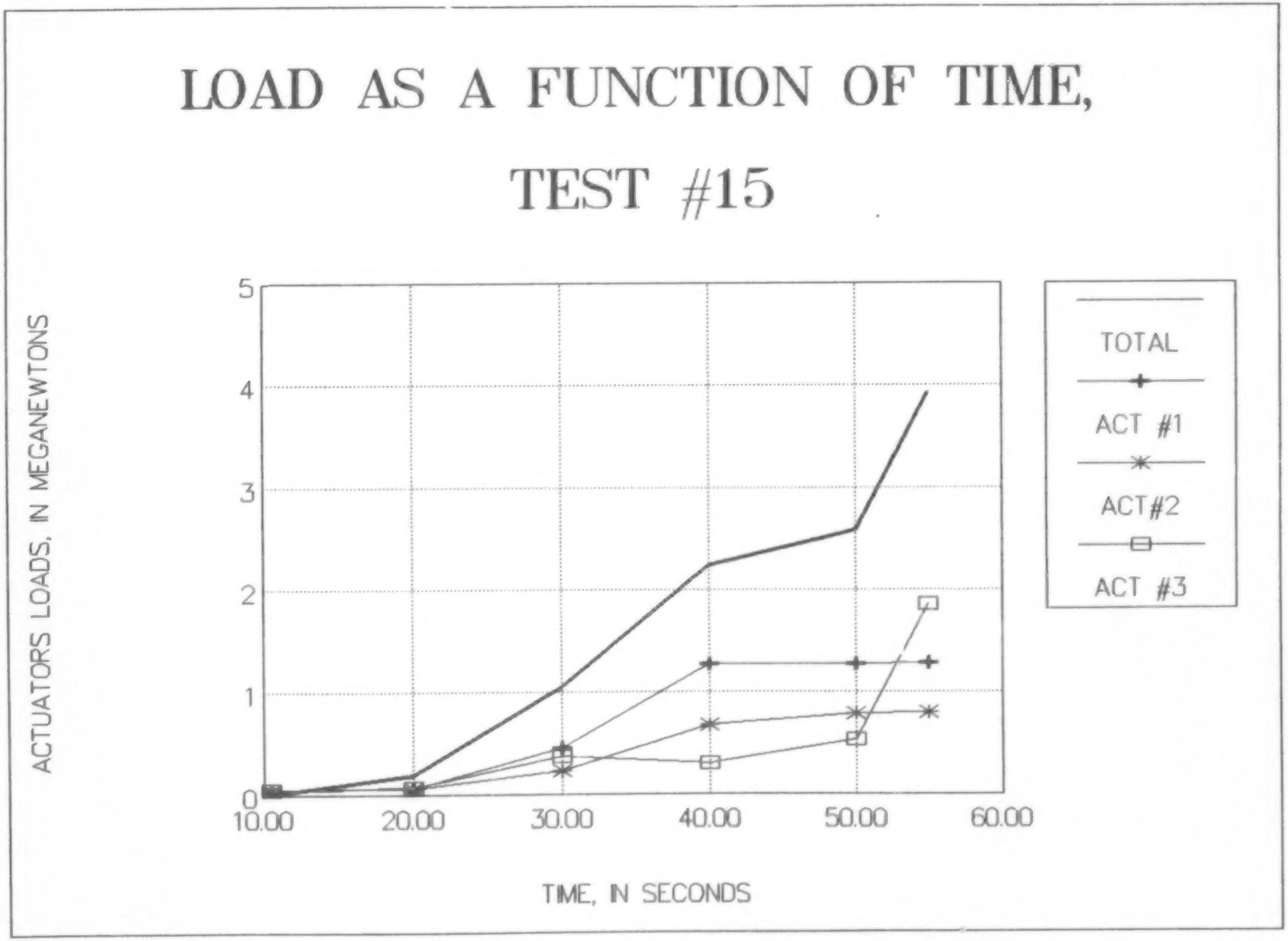

LOCATION OF THE CENTER OF EFFORT ON THE BLADE

Figure 5.2.7.



CHANGE OF THE CENTER OF EFFORT AS A FUNCTION OF LOAD MAGNITUDE

Figure 5.2.8.



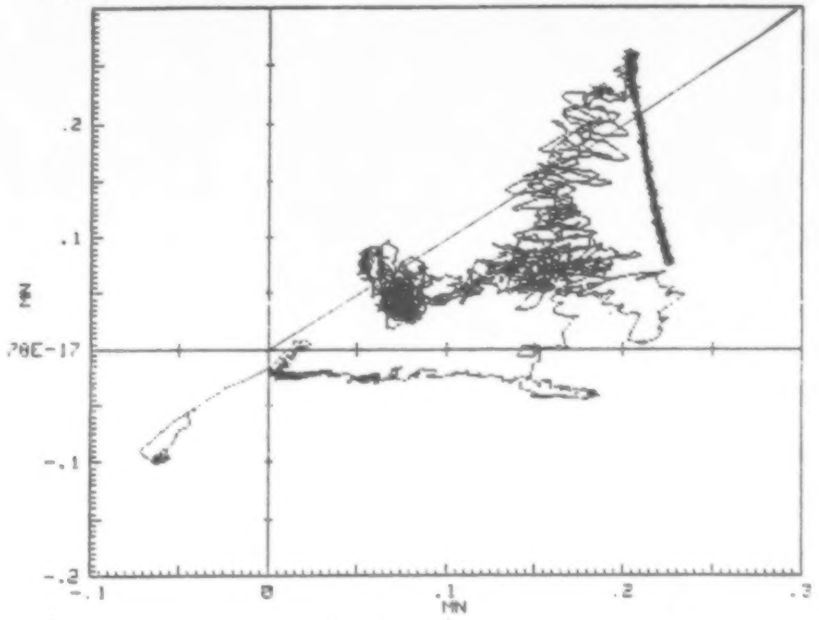
LOAD AS A FUNCTION OF TIME,

TEST #15

Figure 5.2.9.

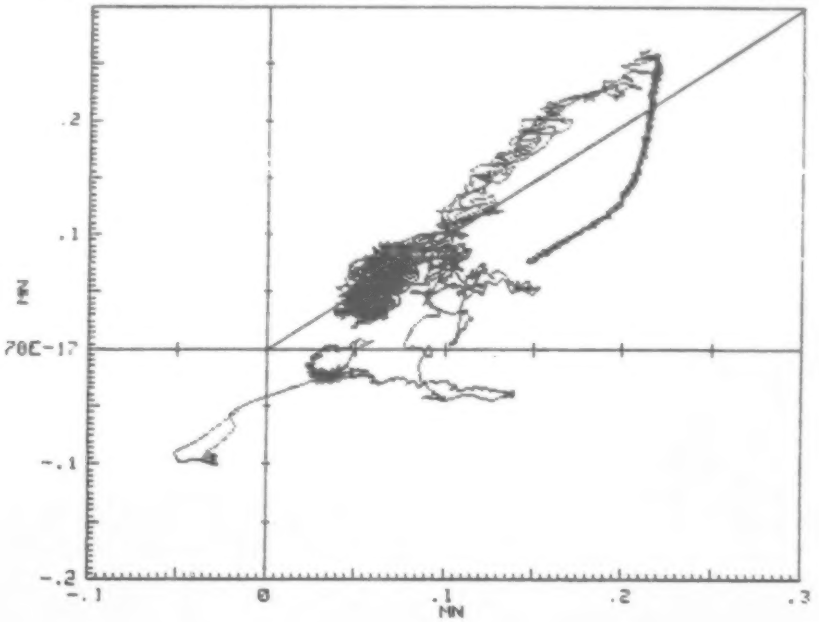
GEOTECHnical Resources Ltd. ANALYSIS DATE: 6 May 1988

1AL1 vs. 1AL3 **Series PBT Test 1**



GEOTECHnical Resources Ltd. ANALYSIS DATE: 6 May 1988

1AL1 vs. 1AL2 **Series PBT Test 1**



5.3. Analysis of the pressure distribution in the interaction zone.

Method

While the loads on the actuators indicate the general distribution of the loads and pressures, the local distribution of the pressures in the interaction zone was obtained by analyzing the signals from the 5 pressure pickups. Figure 5.2.1 shows the locations of the pressure pickups on the pressure side of the blade. The approximately rectangular area covered has a surface area of 0.43 m^2, that is approximately 1/2 of the total ice contact area for many tests. One pressure pickup had a diameter of 0.075m and surface area of

0.0044 m^2.

Total pressure pickups area is:

0.022 m^2,

which is **1.5%** of the bucket area of

1.5 m^2.

They were mounted flush with the blade surface.

Figure 5.3.2a and 5.3.2b show the configuration of the pressure pickups against the position of the bucket for the tests 1 to 6 and 7 to 19, respectively.

Results - pressure characteristics

Table 5.3.1 summarizes the maximum pressure readings recorded during the tests.
The maximum pressure occurring during the peak load was:

29.0 MPa

which was recorded during the test 15, on BP3. Figure 5.3.3 shows the trace of this pressure recording. The average of the maximum pressures recorded was:

3.26 MPa

The average bucket pressure (maximum total load/bucket area) was **0.8 MPa,** while the pressure maximum was **2.71 MPa.**

The maximum apparent pressure (maximum total load/ initial contact area) was **7.67 MPa**, while the average was **2.38 MPa**

Figure 5.3.4 shows the maximum pressure/area distribution, for all tests. Characteristic decay is apparent. It should be noted that this curve is an envelope of the different pressure readings, from different tests.

Table 5.3.2 summarizes the peak pressure characteristics for the tests. Most of the peak pressures (8 out of 15) were recorded by BP3.

Pressure readings from the pickups exhibit considerable scatter when compared with other variables. See Figure 5.3.5 for the comparison of the average and the max - min values. An exception are the creep tests (#14 and #15) where a very ordered relationship between the average/maximum pressure is compared with the maximum load. See Figure 5.3.6, from which a straight proportion between the variables is apparent.

This is so because during the creep tests there were no major local failures of ice and the pressure was equally distributed throughout the contact area. During the high velocity tests, the local pressures were reflecting the local strength of the ice and the local contact geometry, varied largely throughout the tests.

Figure 5.3.7 shows the peak pressure recorded by the pickups and the total load. Large scatter is apparent, but there is a correlation between the two. The best fit line is also shown in the graph.

Figure 5.3.8 shows the dependence of the average of the maximum pressures from the pickups on the total maximum load. Large scatter precludes drawing any definite conclusions, other than the maximum load did lead to the maximum average pressure.

Figure 5.3.9 shows the peak and the average of the maximum pickup pressures as a function of the bucket maximum pressure. Linear proportionality is clear, for both variables.

Figures 5.3.10 shows the correlation of the average of the maximum pickup pressure with the apparent pressure. Lack of a strong correlation is clear.

Figure 5.3.11 shows the correlation between the maximum of maximum pickup pressures and the apparent pressure. A stronger than in the previous case correlation emerges.

Figure 5.3.12 shows the dependence of the maximum bucket pressure on the apparent pressure, for all tests. The linear dependence between the two variables is clear.

*The same correlations based on the tests **done with ice only** and the **first time indentation only** show considerably less scatter. Figures 5.13 to 5.15 and the correlations are stronger.*

Figure 5.3.16 shows the duration of the peak pressure as a *function of its magnitude. Although some tests do not comply with the trend, the proportionality is apparent.*

An examination of the individual pressure pickup signals recorded during the tests lead to the following observations:

1. *Pressure buildup is gradual and slow in comparison with the rapid drop after the local ice failure (tests 1,2,4 and others).*

2. *Two types of pressure buildup are apparent:*

   ductile, characterized by a slow and smooth buildup (test 6,14), and
   brittle, characterized by a pressure buildup thru the series of failures (test 2)

3. *The ductile type of pressure buildup is characterized by the post failure high magnitude of the residual pressure (test 2).*

4. *In many cases the pressure builds up even after the indentation process has stopped (test #7, 8). This is due to the ongoing creep and the removal of crushed ice from the contact zone.*

5. *Time histories of the pressures and time histories of the loads are often not compatible. The pressure buildups are much faster than the load buildups (test 11). This confirms the local, and perhaps random behavior of the ice under pressure.*

6. *Many signals contain a vibratory component during the pressure buildup phase, being the result of the system's mechanical vibrations and ice crushing/extrusion oscillatory process (test #10).*

Results - pressure distribution across the contact area.

Table 5.2 shows that the majority of maximum pressures recorded during tests 1 to 7 were concentrated at pressure gauges BP4 and BP3 which are located at the blade center.

After the bucket was shifted towards the leading edge, the maximum pressures shifted towards the center of the load triangle (BP3), which is when the sensor recorded the most (except test 19) maximum pressures.

The pressure pickup BP2, located near the blade corner saw the least pressure, both in terms of the averages and maxima recorded.

The pressure pickup BP5, located near the leading edge, did not *record any of the maximum pressures, and its maximums recorded values were only about 1/2 of all the maximums recorded.*

Thus it can be concluded that:

- *the peak pressures are taking place at the middle of the apparent contact area.*

Run #9 has a complete set of the pressure pickup recordings and therefore will serve as an illustrator of the pressure distribution during the tests.

Figures 5.3.17 to 5.3.19 contain the traces of all of the blade surface pressure signals.

The first pressure buildup was recorded on the BP1, at approximately 1.74 sec into the test. During the buildup, lasting until 2 sec, BP2 saw only small perturbations about the mean, of a vibratory nature. BP4 was the second pickup which started the pressure buildup before the two seconds elapsed. Gauge BP3 did not see any load until 2.4 sec into the test.
At two seconds into the test, an ice failure took place which resulted in a rapid peak of the pressures at BP1, BP2,BP4 and BP5. A rapid decay of the pressures followed, associated with some vibrations and little residual pressure.
At 2.4 seconds into the test,a second peak was recorded, this time achieving the maximum at BP3, followed by a number of smaller peaks and oscillatory behavior.
At 2.7 sec into the test, the advance of the plungers was stopped and pressures returned to zero.

The following observations can be made from this description:

Only two of the gauges (BP1 and BP4) saw a pressure buildup characteristic of ice compression. This buildup lead to the highest recorded pressures (6.18MPa and 7.20MPa respectively). The buildup time history was similar to the buildup of the total actuators load.
This can be considered as an ***active pressure buildup, as the*** *pressure is the result of ice loading.*

The following buildup leading to the second peak load and second ice failure occurred at approx 2.4 sec into the test. At that point,all gauges saw only the rapid transients of the pressure due to the blade response to ice failure elsewhere in the contact area.
This can be considered as a ***passive pressure response****, as the pressure is the result of the blade rebouncing against the ice.*

In this test, the pressure pickups across the blade exhibit the ***distributive property,*** *ie the loads on some pickups are associated with near zero loads on the other, and vice versa. The load is being distributed unevenly among the various areas on*

the blade. Failure of ice in one area loads another zone until failure is occurring there etc.
If the ice and blade were perfectly rigid bodies, the contact zones could have been limited to 1 point only. This is so because both the **blade and the ice are constrained**. *(Three contact points would be necessary to maintain the equilibrium if one body would not have be constrained).*
Failure of the ice at a contact point transfers the contact point elsewhere. With the ice and blade being elastic materials, the contact point may be distributed among some finite area, nevertheless one area only is required to support the load.

Run #15 is a good example of the similar behavior of ice and resulting pressure distribution.

Pressure transducers BP3 and BP4 do not see any load until well into the test. The pressure buildup is very gradual in both cases, but they are not in phase. Overall load buildup starts at 18 seconds into the test. BP3 starts the strong pressure buildup at 23 seconds, culminating in the ice failure at that location at 32 seconds into the test. BP4 starts the pressure buildup at 42 seconds into the test, culminating in ice failure at 55 seconds. In this test, both gauges respond actively to the ice pressure. Both their response is shifted in time and out of phase,as the center of effort is shifting within the ice mass and that the two regions, separated by a distance of approximately 0.4m are not working together.
Also it is worthwhile to note that the blade response influences the location of the contact point. The initial load being carried by the area near BP3 deflects the blade away from the plungers which shifts the contact area lower down, into the region occupied by BP4. That is why the BP4 saw the large load the last.

Figure 5.3.20 shows the correlation of the pressure at BP3 versus the total load developed during the test #11. A characteristic "S" shape curve is apparent, as pressure buildup elsewhere carries the initial load, which, after a local ice failure there, is then transferred to the vicinity of BD3.

Figures 5.3.21 to 5.3.24 show the maximum pressures recorded during the tests 1, 9, 12 and 15, respectively. The bars are proportional to the pressure, in MPa recorded during the tests.

Note that during the first two tests shown the maximum pressures were distributed across the contact area, while for the two remaining tests, the high pressures were concentrated at one location.

Conclusions

The following conclusions are drawn from this investigation:

1. The maximum pressures recorded during these tests were:

   32.64 MPa (compressive stress in an actuator)
   29.00 MPa (blade pressure pickup BP3)

2. Maximum pressures recorded during this test series follows the typical pressure/area distribution curve.
3. The maximum pressure was recorded during the creeping tests.
4. The majority of the maximum pressures were picked up at the geometric centers of the load application areas.
5. Peak local pressures are, in general, not occurring at the moment of the peak loads.
6. Average and maximum pressures are strongly linked with the maximum loads only during the creeping tests.
7. There is a linear correlation between the peak pressure and the peak total load.
8. There exists a large scatter of the maximum pressure readings and other interaction parameters.
9. The maximum load recorded lead to the maximum pressure recorded.
10. The maximum pressure recorded was approximately four times the average pressure recorded.
11. Duration of peak pressure is proportional to its magnitude.
12. Pressure buildup always takes a longer time than the pressure relief.
13. Two types of pressure buildup are identified:
    ductile, and
    brittle.
14. Time histories of the individual pressure buildups and total load buildup are often not compatible.
15. Pressure pickups located near the blade leading edge recorded lower maximum and average pressures than those located near the center of the blade.
16. Pressure pickups located near the root saw higher maximum pressures than those located near the tip.

17. The highest pressure was picked up at the center of the load application area and it was approximately 5 times higher than the average of the maximum pressures picked up by all the gauges.

18. There are two types of pressure response:

    active pressure buildup, and
    passive pressure response.

19. Blade response influences the location of the contact and high pressure zone. High loads tend to shift the contact zone towards the blade root.

20. The pressure area has a distributive property,that is a high pressure in one spot leads to a low pressure in another, and vice versa.

21. The initial contact area and the location of the high pressure zone depends on the initial ice configuration. The final area depends on the response of the blade.

22. Two adjacent regions of the blade may not be working together against the ice pressure.

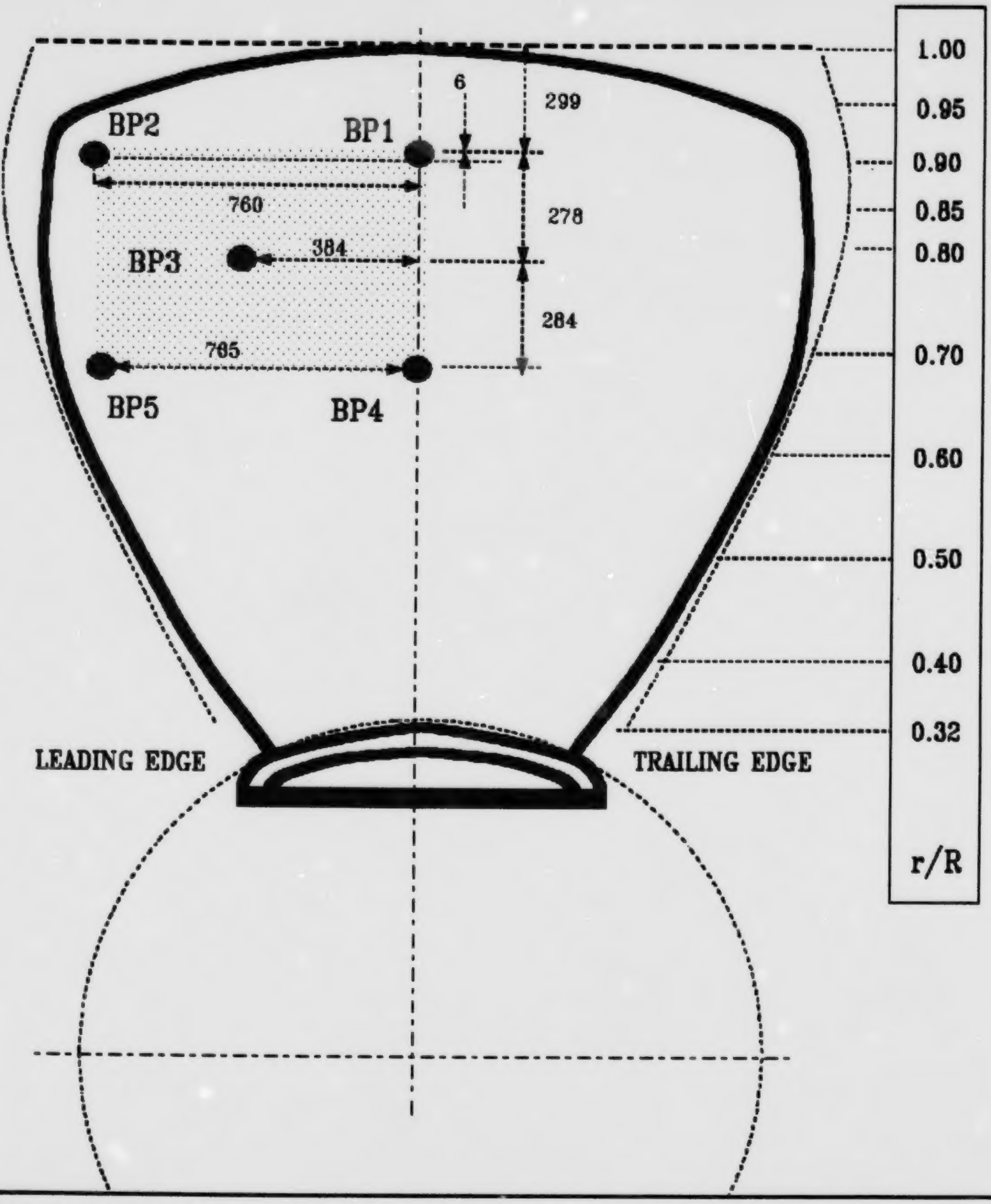

BP2
BP1
6
299
760
278
384
BP3
284
765
BP5
BP4
LEADING EDGE
TRAILING EDGE
1.00
0.95
0.90
0.85
0.80
0.70
0.60
0.50
0.40
0.32
r/R

FIGURE TITLE: ARRANGEMENT OF THE PRESSURE GAUGES ON THE PRESSURE SIDE

PROJECT NAME: FULL SCALE TESTS ON THE BLADE RESPONSE TO ICE LOADS

DRAWN BY: VL	CHK'D BY: VL	SCALE: NONE	FIGURE NR: 5.3. 1

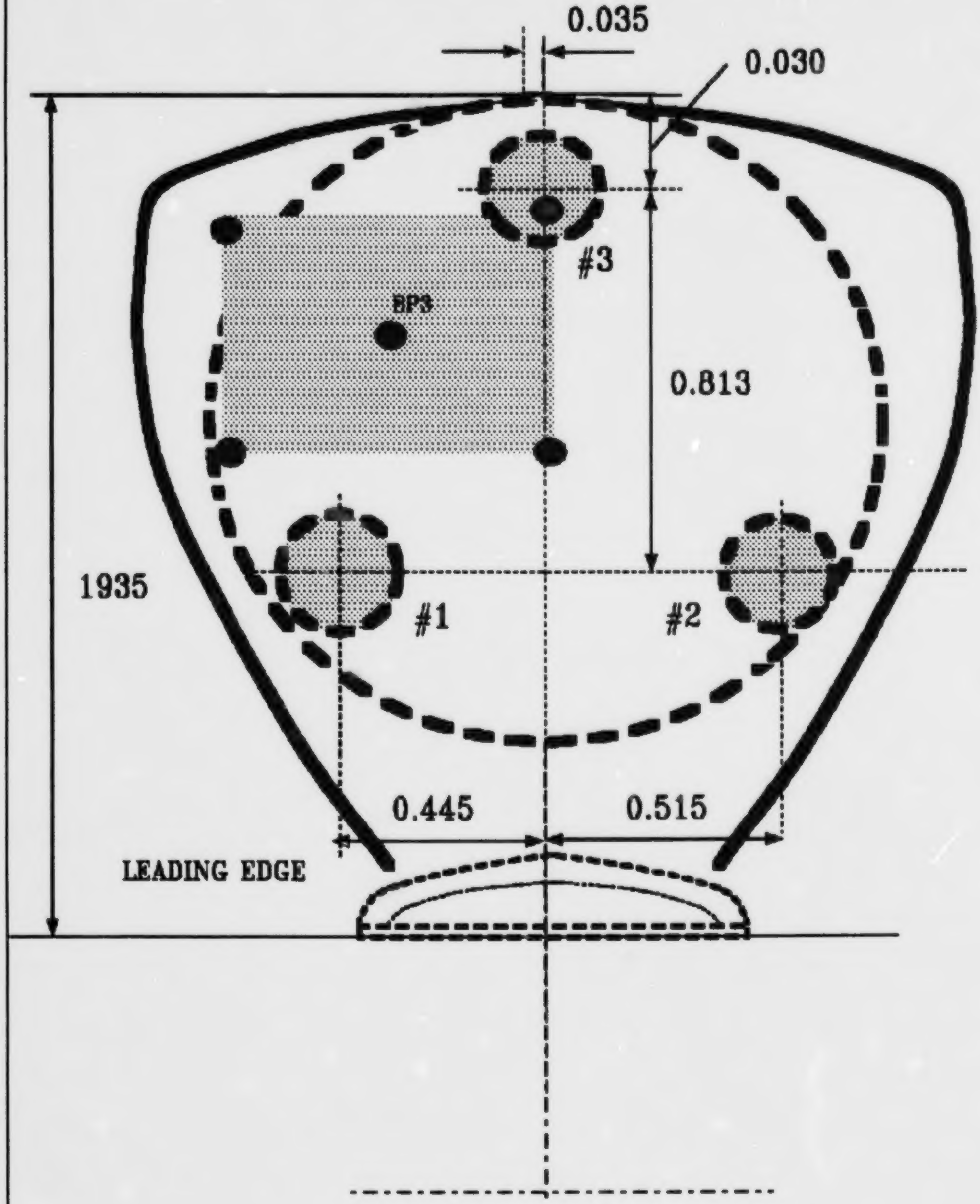

0.035
0.030
#3
BP3
0.813
1935
#1
#2
0.445
0.515
LEADING EDGE

FIGURE TITLE: ARRANGEMENT OF THE PRESSURE GAUGES ON THE PRESSURE SIDE OF THE BLADE

PROJECT NAME: FULL SCALE TESTS ON THE BLADE RESPONSE TO ICE LOADS

DRAWN BY: JERVL	**CHK'D BY:** VL	**SCALE:** NONE	**FIGURE NR:** 5.3.2A

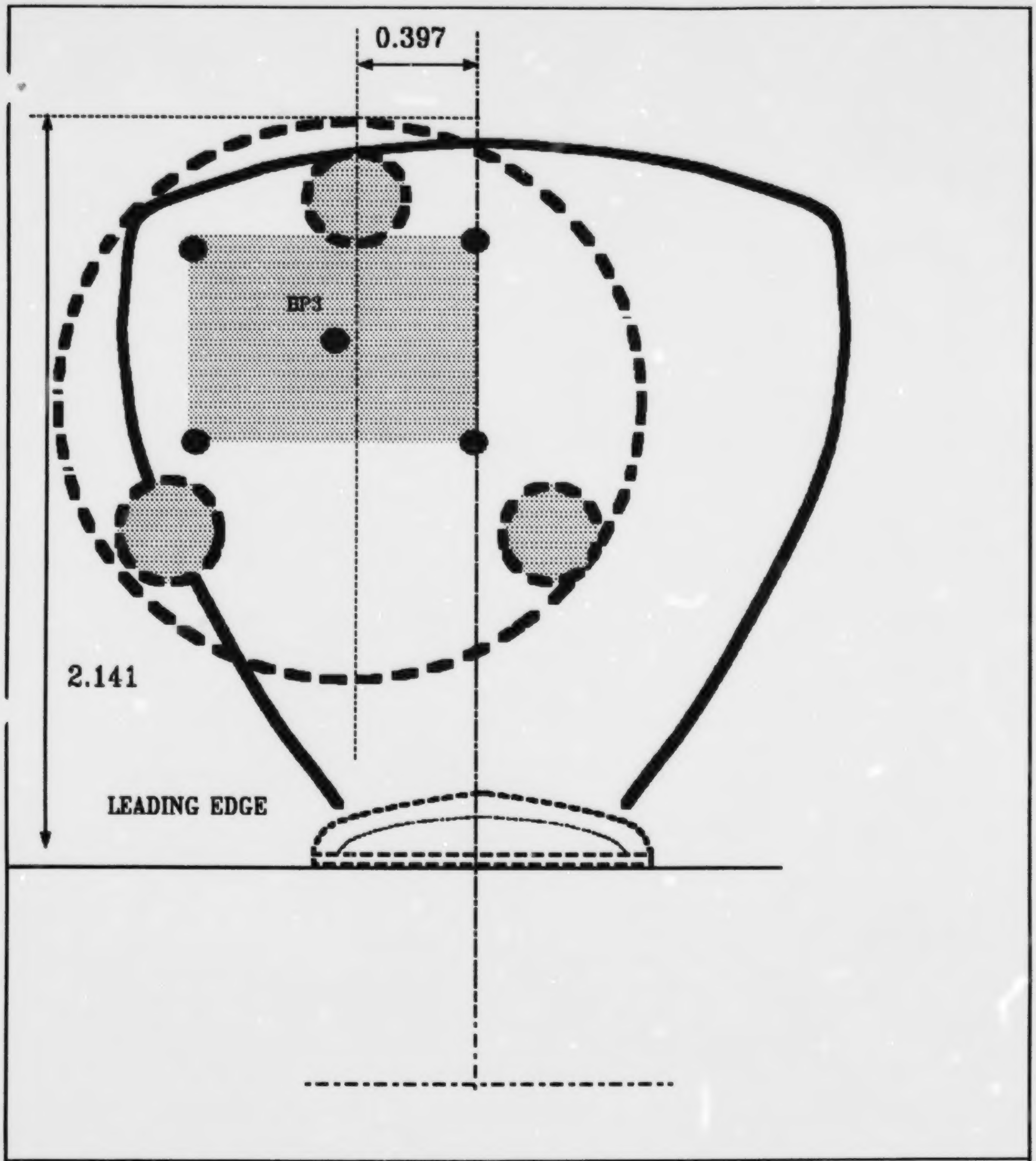

0.397
BP3
2.141
LEADING EDGE

FIGURE TITLE: ARRANGEMENT OF THE PRESSURE GAUGES ON THE PRESSURE SIDE OF THE BLADE			
PROJECT NAME: FULL SCALE TESTS ON THE BLADE RESPONSE TO ICE LOADS			
DRAWN BY: JERVL	**CHK'D BY:** VL	**SCALE:** NONE	**FIGURE NR:** 5.3.2B

ARAD

TABLE 5.3.
PRESSURES MEASURED DURING THE TESTS

TEST	ICE	CONT	MAX	APPARENT	MAX PRESSURE DURING THE TESTS					PRESSURE, IN MPa			BUCKET
NR	TYPE	AREA	LOAD	PRESSURE	BP1	BP2	BP3	BP4	BP5	AVGE	MAX	MAX	PRESSURE
		M^2	MN	MPa			MPa			MPa	MPa	-MIN	MPa
1	BLOCKS	1.00	0.66	0.66	3.48		7.64	8.15	5.49	6.19	8.15	4.67	0.44
2	CRUSHED	1.54	0.53	0.34			1.11	0.94		1.02	1.11	0.17	0.35
3	CRUSHED	1.20	0.53	0.44	6.06	3.55	2.01	1.04		3.16	6.06	5.02	0.35
4	CRUSHED	0.68	1.03	1.51	1.87		3.29	8.41	4.12	4.42	8.41	6.54	0.68
5	CRUSHED	0.60	0.37	0.62	2.24		0.30	2.28		1.61	2.28	1.98	0.25
6	CRUSHED	0.10	0.57	5.70	2.11	3.62	2.35	2.01	0.54	2.12	3.62	3.08	0.38
7	CRUSHED	0.38	0.37	0.97	1.80	1.14	4.16	2.11	0.17	1.88	4.16	3.99	0.25
8	CRUSHED	0.68	0.53	0.78	7.16	1.20	6.10	0.18	0.33	3.00	7.16	6.98	0.35
9	CRUSHED	1.25	1.28	1.02	6.39	3.72	4.16	7.54	6.60	5.68	7.54	3.83	0.85
10	CRUSHED	0.91	0.42	0.46	0.40	0.40		0.17		0.32	0.40	0.23	0.28
11	CRUSHED	0.91	1.13	1.24	2.51	2.21	6.20	0.27	0.65	2.37	6.20	5.93	0.75
12	CRUSHED	1.25	1.27	1.02	6.69	2.25	13.31	2.40	1.53	5.24	13.31	11.78	0.84
13	ABORTED												
14	CRUSHED	1.25	1.75	1.40		0.13	12.31	0.13	0.10	3.17	12.31	12.21	1.16
15	CRUSHED	0.60	3.93	6.55		0.57	29.00	1.00	0.87	7.86	29.00	28.43	2.61
16	VIBRATIONS												
17	VIBRATIONS												
18	TIMBER	0.30	2.05	6.83		0.17	5.80	0.17	0.17	1.58	5.80	5.63	1.36
19	TIMBER	0.30	2.40	8.00	0.57	4.42	1.27	3.32	3.45	2.61	4.42	3.85	1.60
	MAXIMUM	1.54	3.93	8.00	7.16	4.42	29.00	8.41	6.60	7.86	29.00	28.43	2.61
	MINIMUM	0.1	0.37	0.34	0.40	0.13	0.30	0.13	0.10	0.32	0.40	0.17	0.25
	AVERAGE	0.8094	1.18	2.35	3.44	1.95	6.60	2.51	2.00	3.26	7.50	6.52	0.78

Figure 5.3.3.

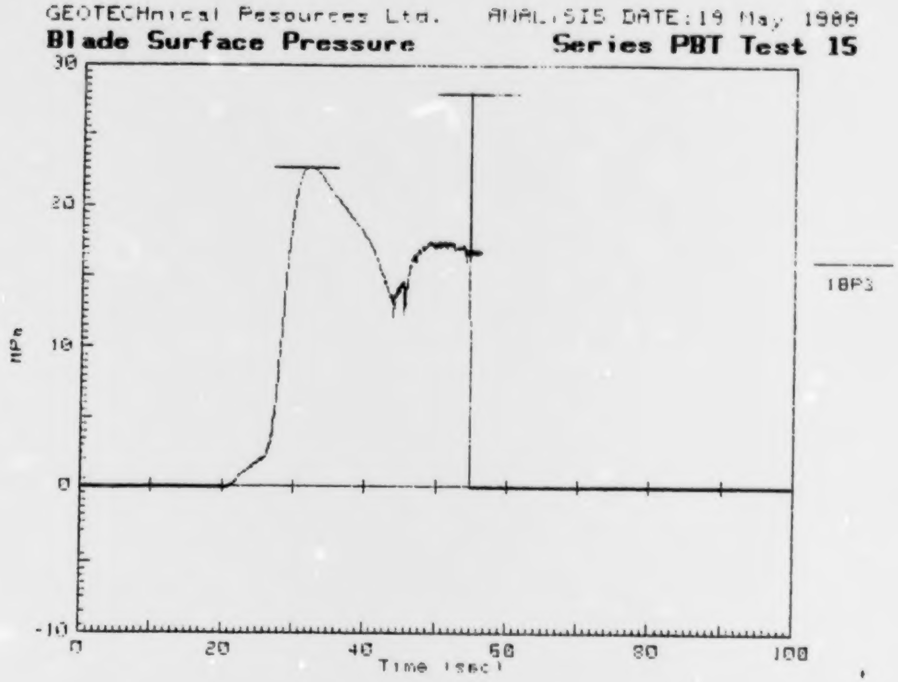
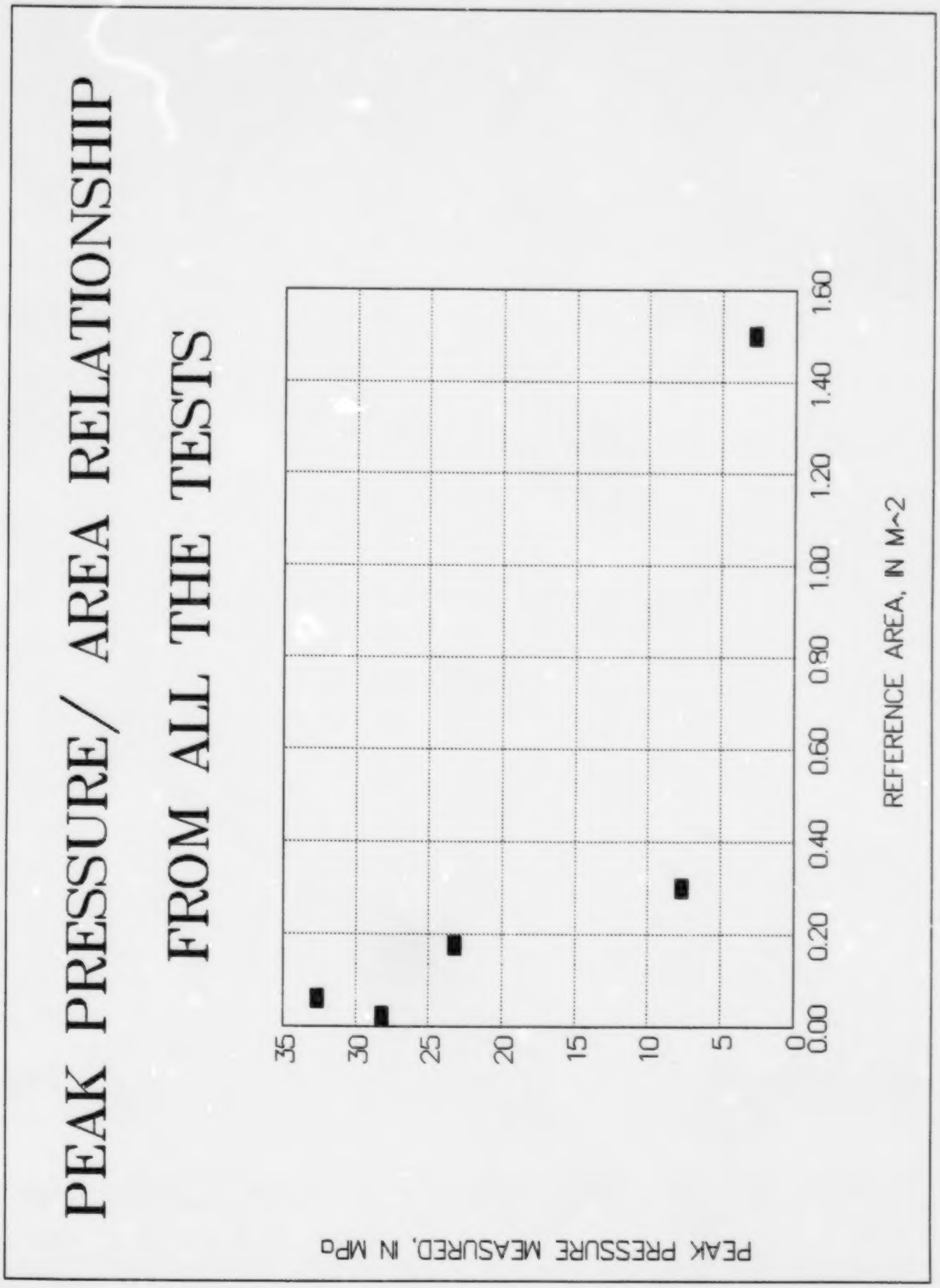

GEOTECHnical Resources Ltd.
ANALYSIS DATE: 19 May 1988
Blade Surface Pressure
Series PBT Test 15
30
20
10
0
-10
MPa
0
20
40
60
80
100
Time (sec)
1BP3

Figure 5.3.4.

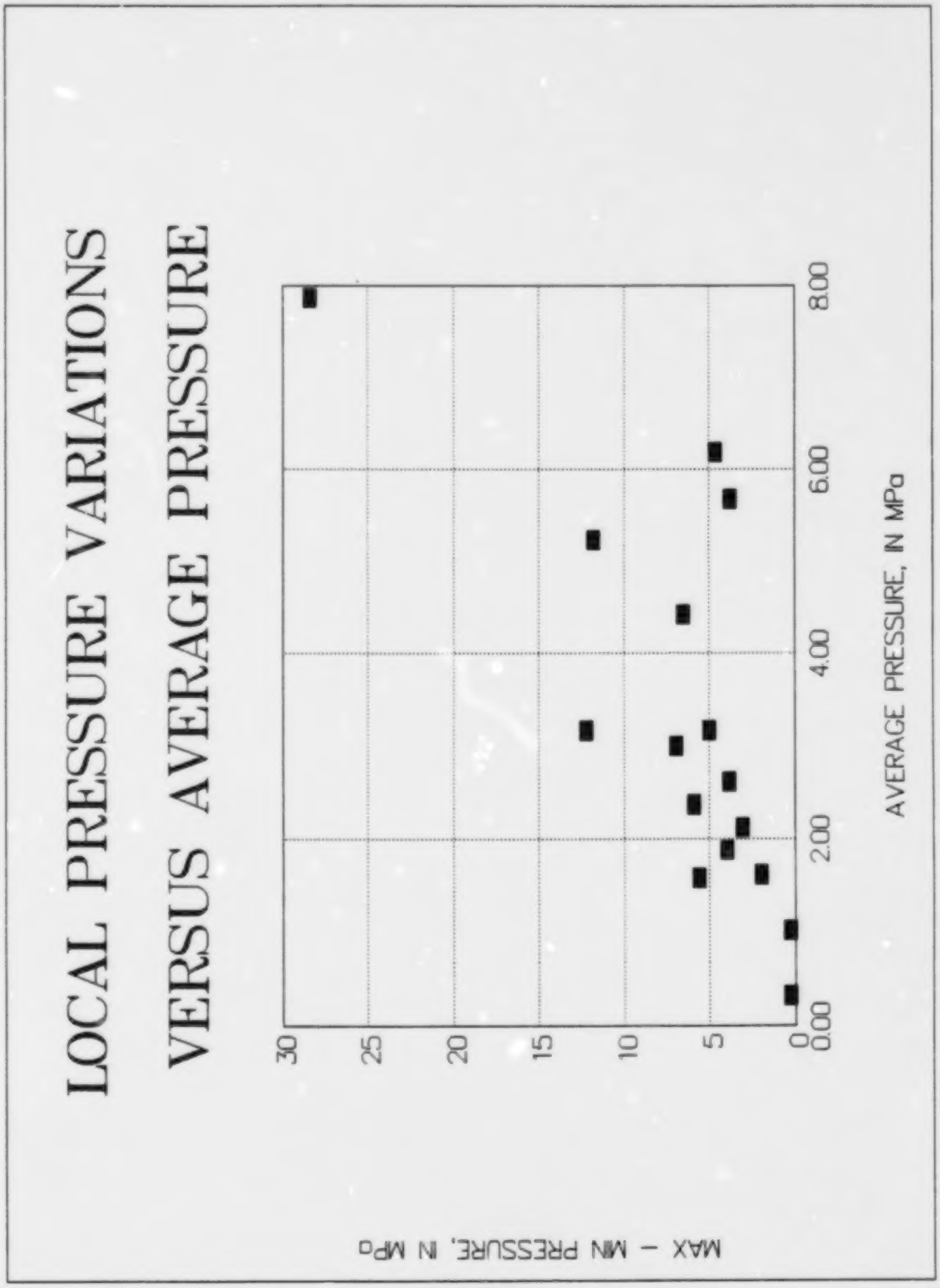


PEAK PRESSURE/ AREA RELATIONSHIP FROM ALL THE TESTS

TABLE 5.3.2
CHARACTERISTICS OF THE PEAK PRESSURES

TEST NUMBER	TOTAL LOAD MN	PEAK PRESS MPa	DURATION OF PEAK SEC	GAUGE NUMBER
1	0.66	8.15	0.80	4
2	0.53	1.11	0.17	3
3	0.53	6.058	0.15	1
4	1.03	8.414	0.12	4
5	0.37	2.28	0.22	4
6	0.57			2
7	0.37			3
8	0.53	7.162	0.10	3
9	1.28	7.543	0.07	4
10	0.42			1
11	1.13	6.203	0.10	3
12	1.27	13.31	0.30	3
13				
14	1.75			3
15	3.93			3
16				
17				
18	2.05			3
19	2.48			2

FIGURE 5.3. 5


LOCAL PRESSURE VARIATIONS
VERSUS AVERAGE PRESSURE
MAX – MIN PRESSURE, IN MPa
AVERAGE PRESSURE, IN MPa
0
5
10
15
20
25
30
0.00
2.00
4.00
6.00
8.00

AVERAGE AND MAXIMUM PRESSURES AS A FUNCTION OF MAX LOAD/CREEP TESTS

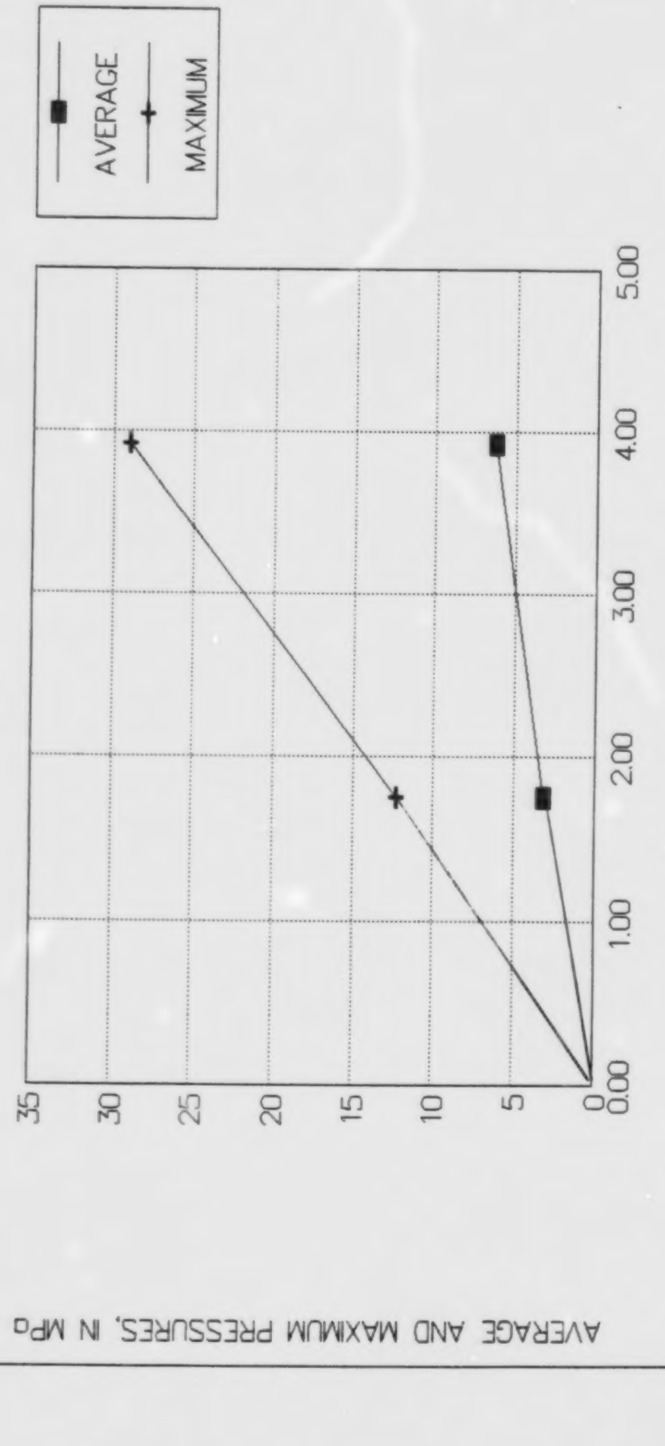
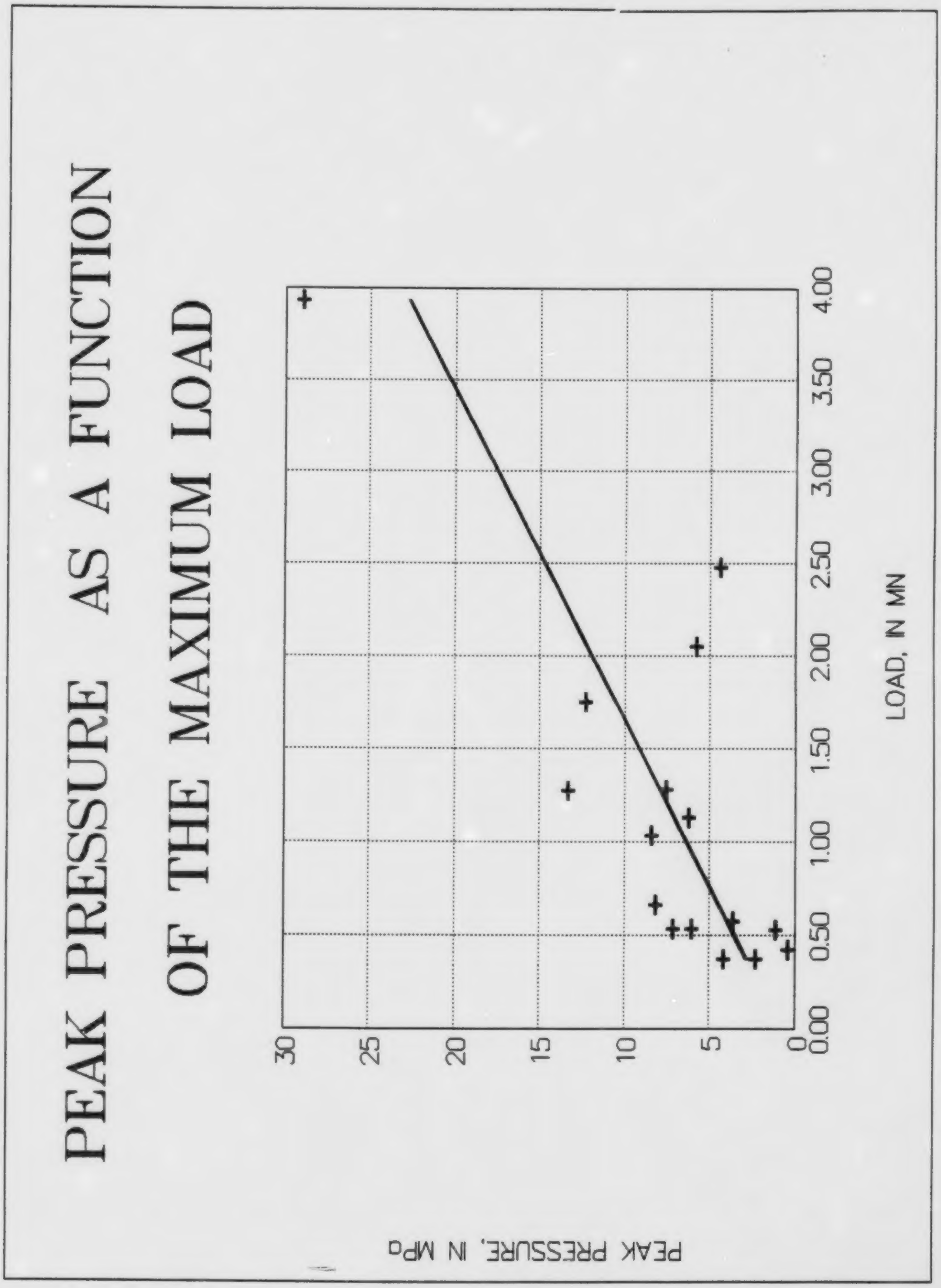


FIGURE 5.3. 7



PEAK PRESSURE AS A FUNCTION OF THE MAXIMUM LOAD

FIGURE 5.3. 8

AVERAGE PRESSURE ON THE PICKUP AS A FUNCTION OF TOTAL LOAD

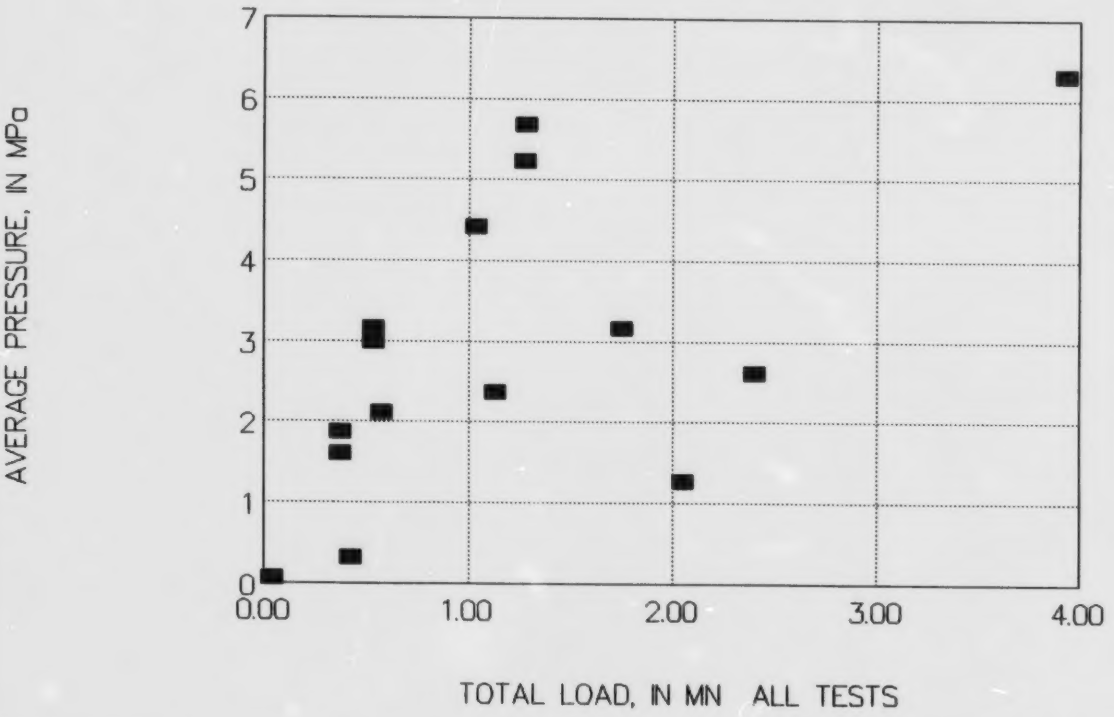


FIGURE 5.3. 9

PEAK AND AVERAGE PICKUP PRESSURE AS A FUNCTION OF BUCKET MAX. PRESSURE

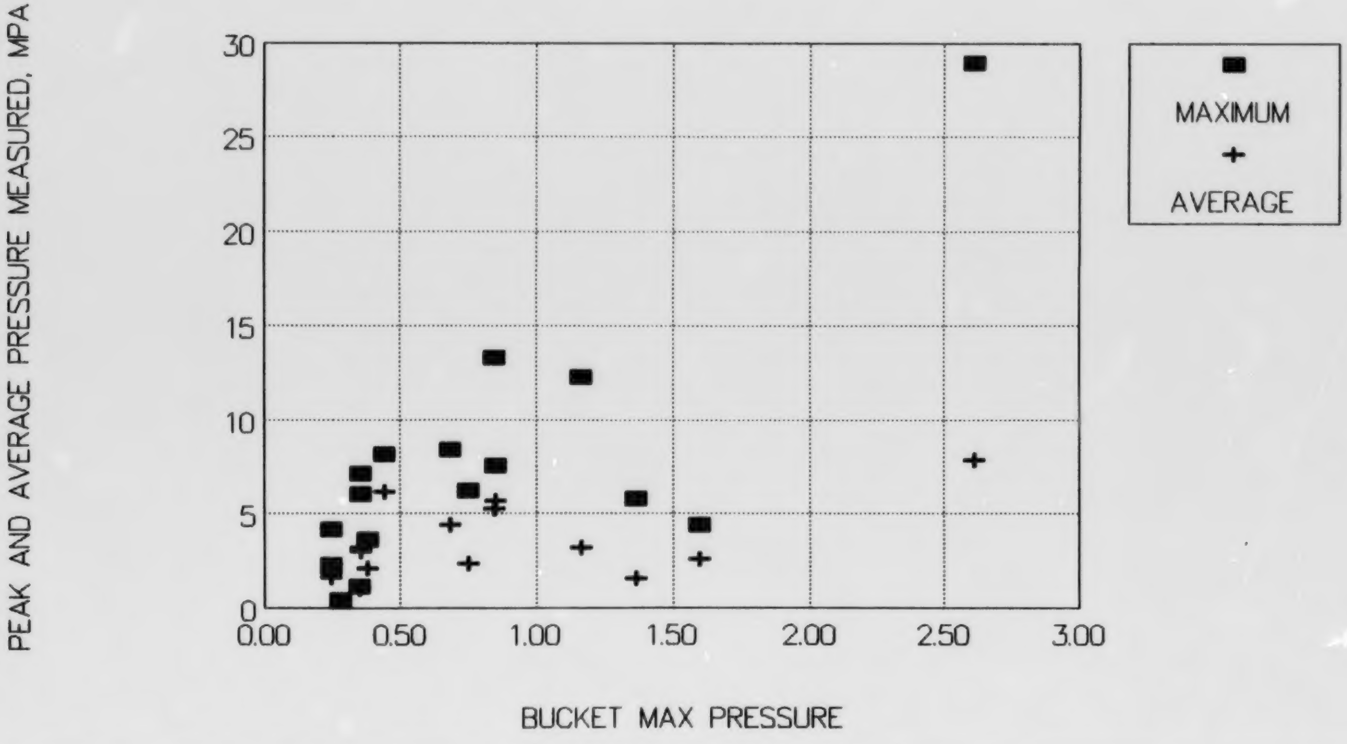


FIGURE 5.3.10

AVERAGE OF MAXIMUM PICKUP PRESSURE AS A FUNCTION OF APPARENT PRESSURE

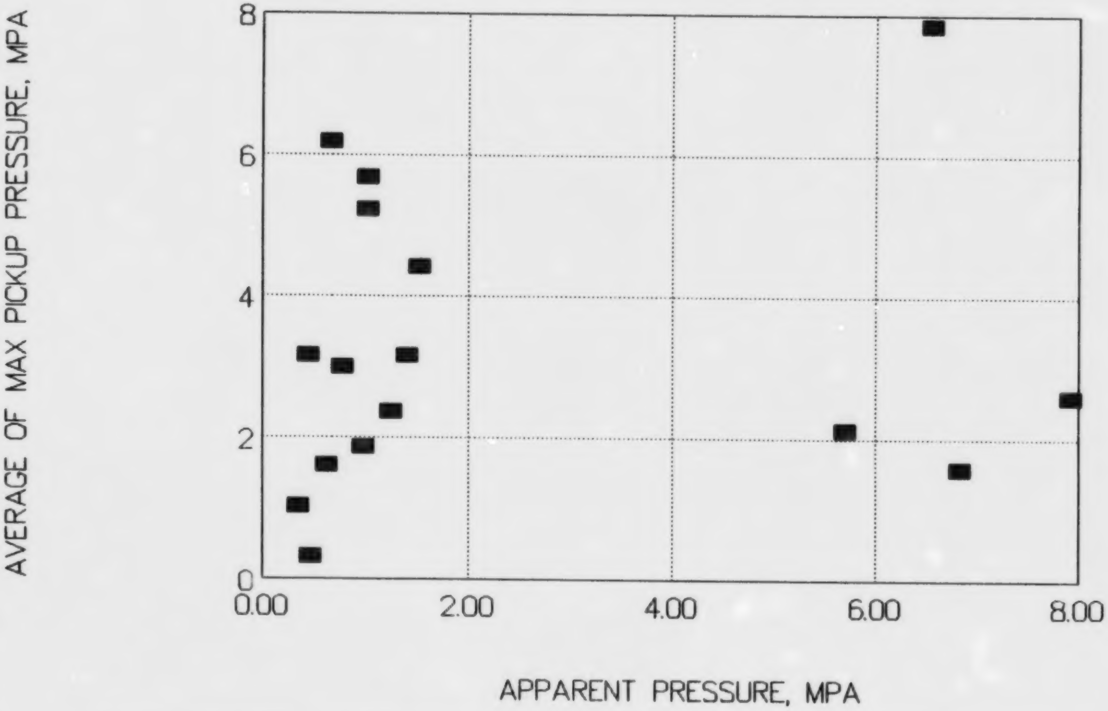


FIGURE 5.3.11

MAXIMUM OF MAXIMUM PICKUP PRESSURES
AS A FUNCTION OF APPARENT PRESSURE

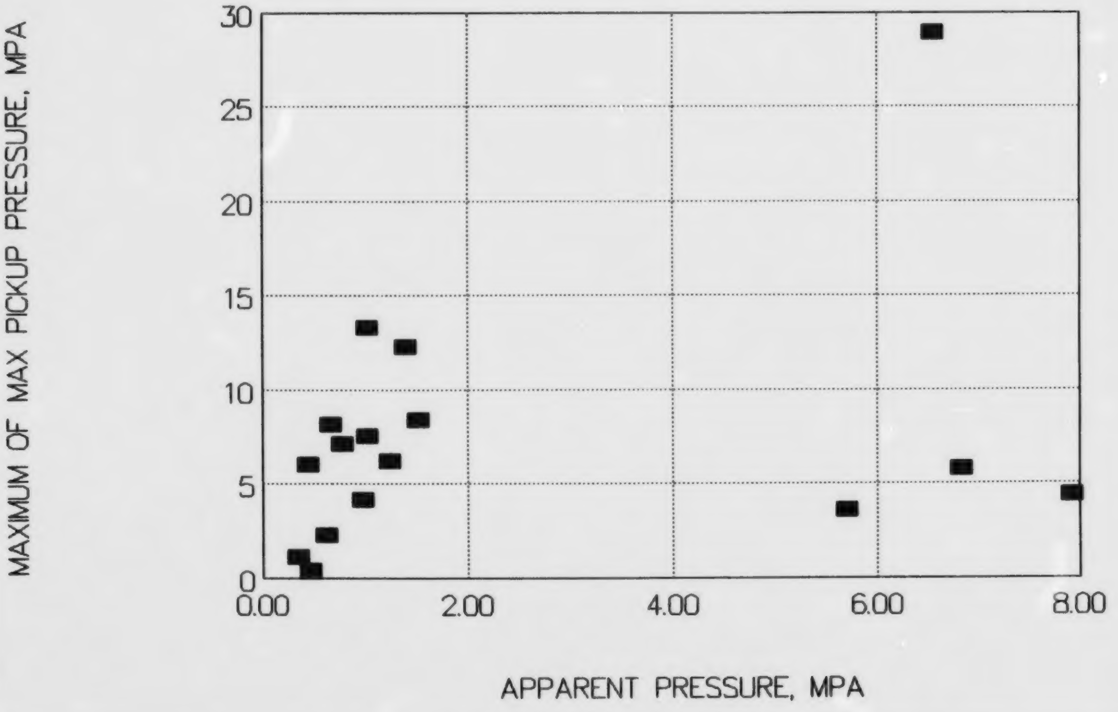


Figure 5.3.12.

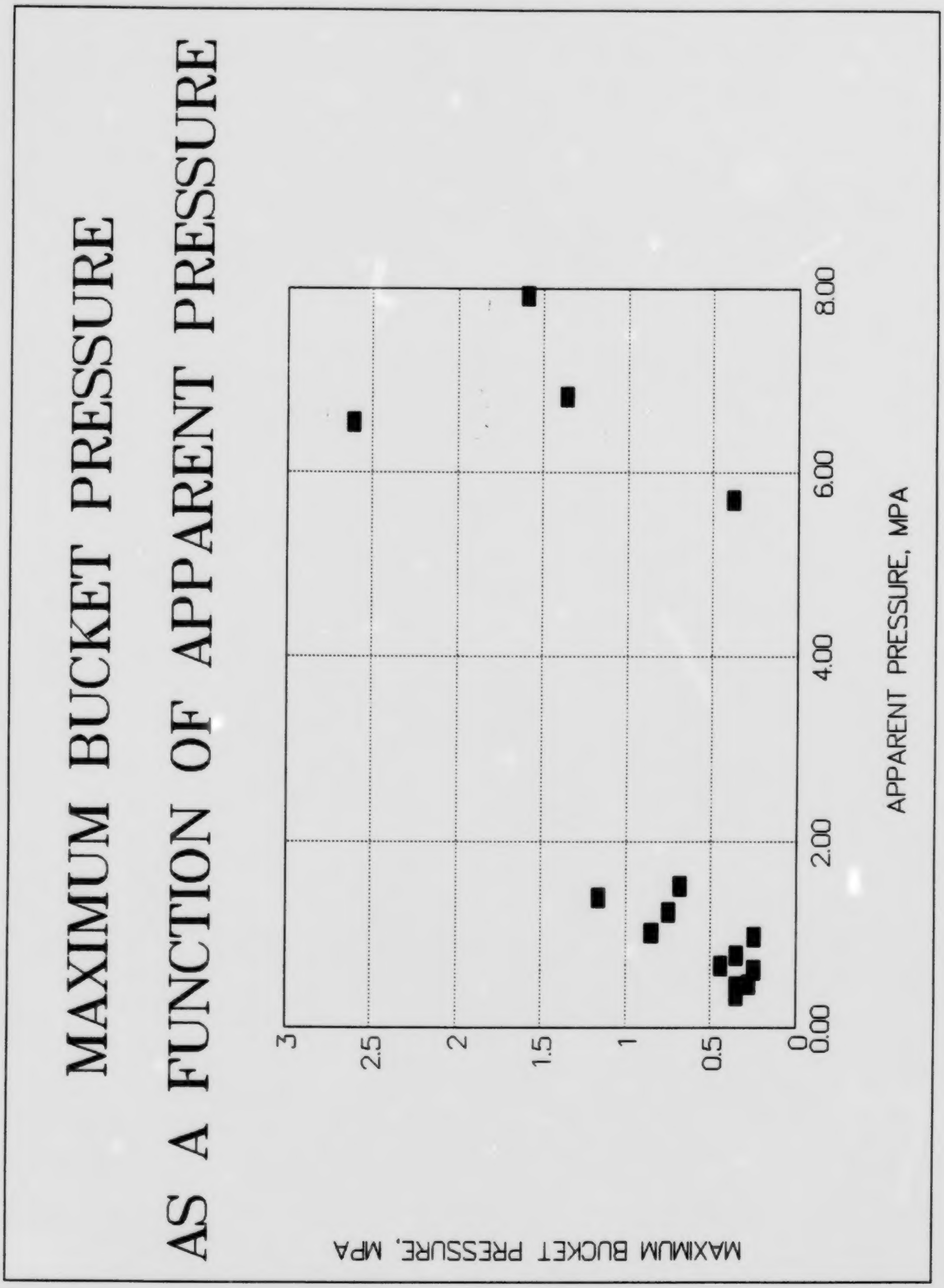
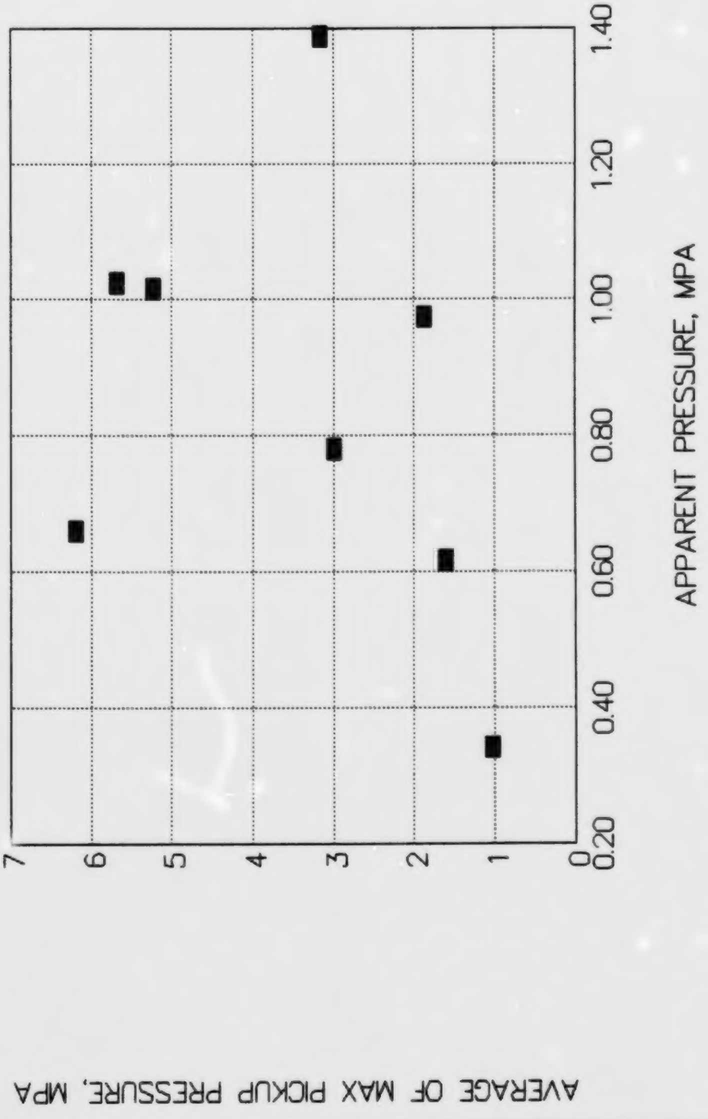
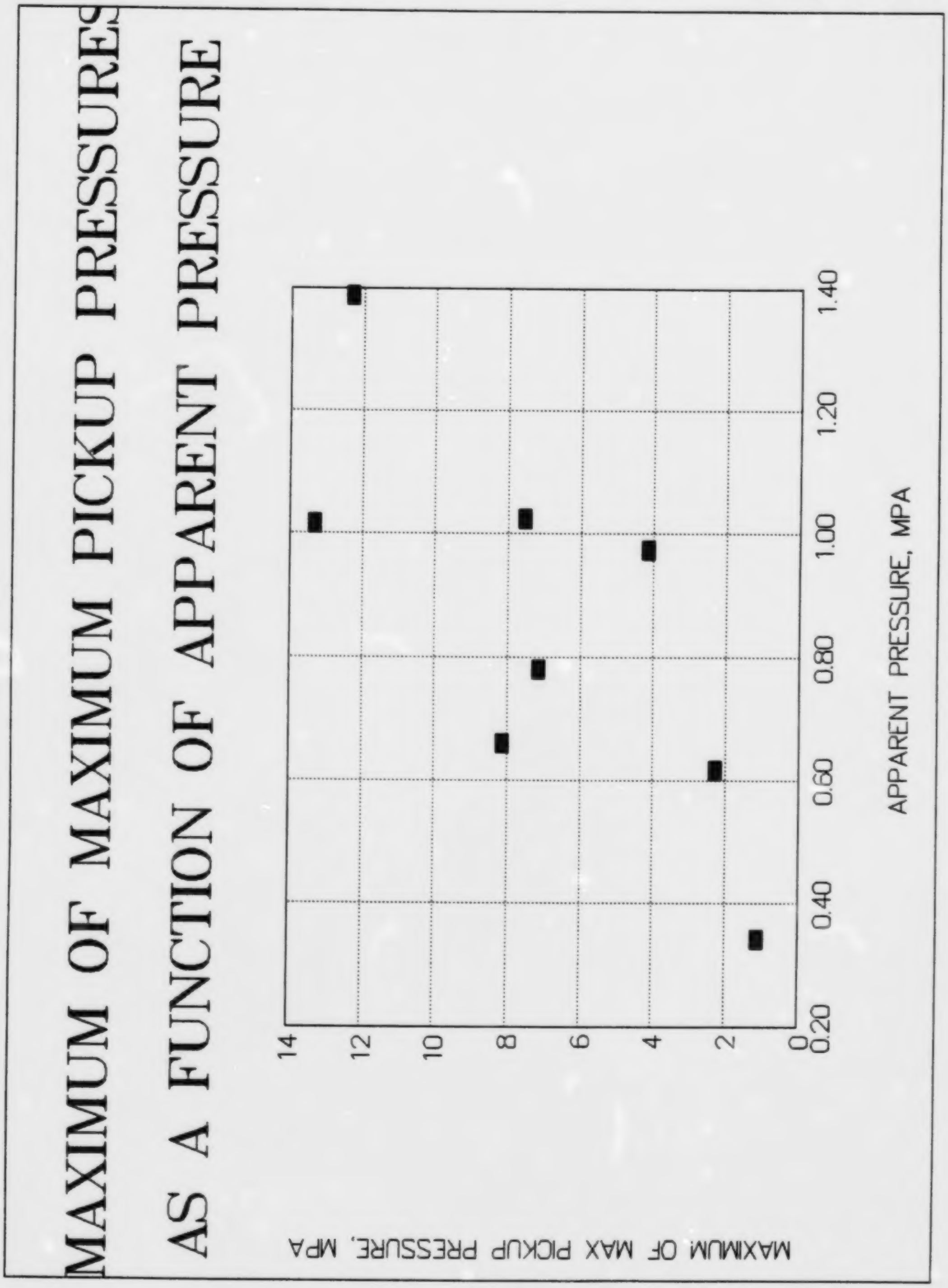

MAXIMUM BUCKET PRESSURE
AS A FUNCTION OF APPARENT PRESSURE
MAXIMUM BUCKET PRESSURE, MPA
APPARENT PRESSURE, MPA
0
0.5
1
1.5
2
2.5
3
0.00
2.00
4.00
6.00
8.00

FIGURE 5.3.13



AVERAGE OF MAXIMUM PICKUP PRESSURE AS A FUNCTION OF APPARENT PRESSURE



MAXIMUM OF MAXIMUM PICKUP PRESSURES AS A FUNCTION OF APPARENT PRESSURE

FIGURE 5.3.15

MAXIMUM BUCKET PRESSURE
AS A FUNCTION OF APPARENT PRESSURE

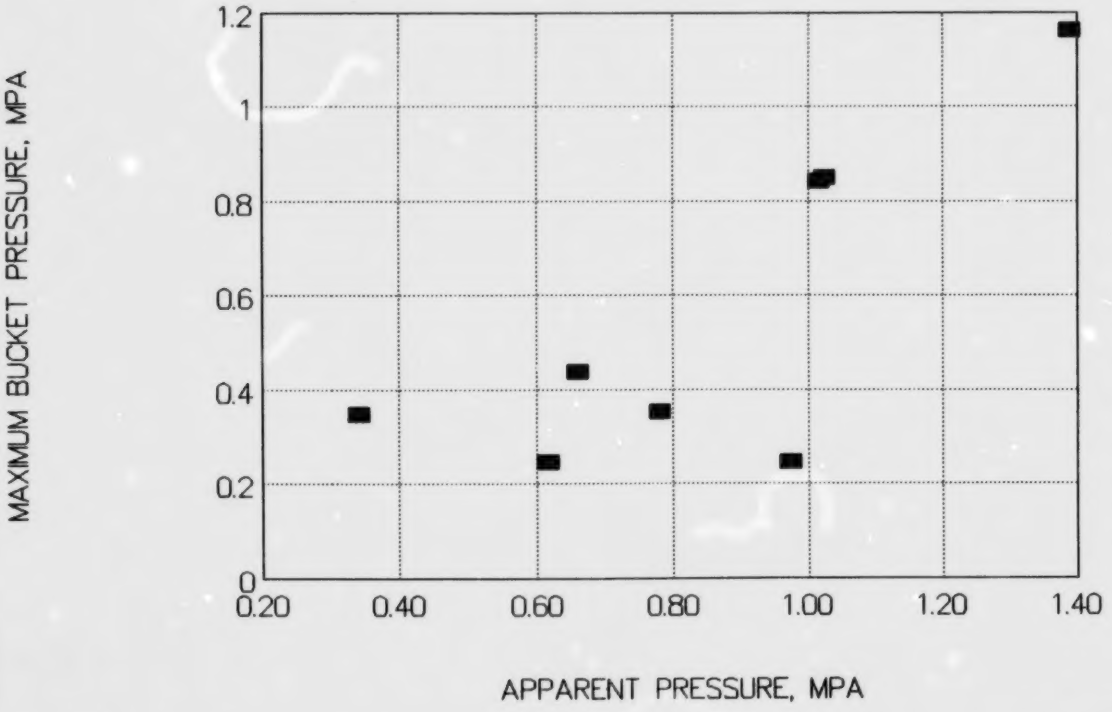


FIGURE 5.3.16

DURATION OF PEAK PRESSURE AS A FUNCTION OF ITS MAGNITUDE

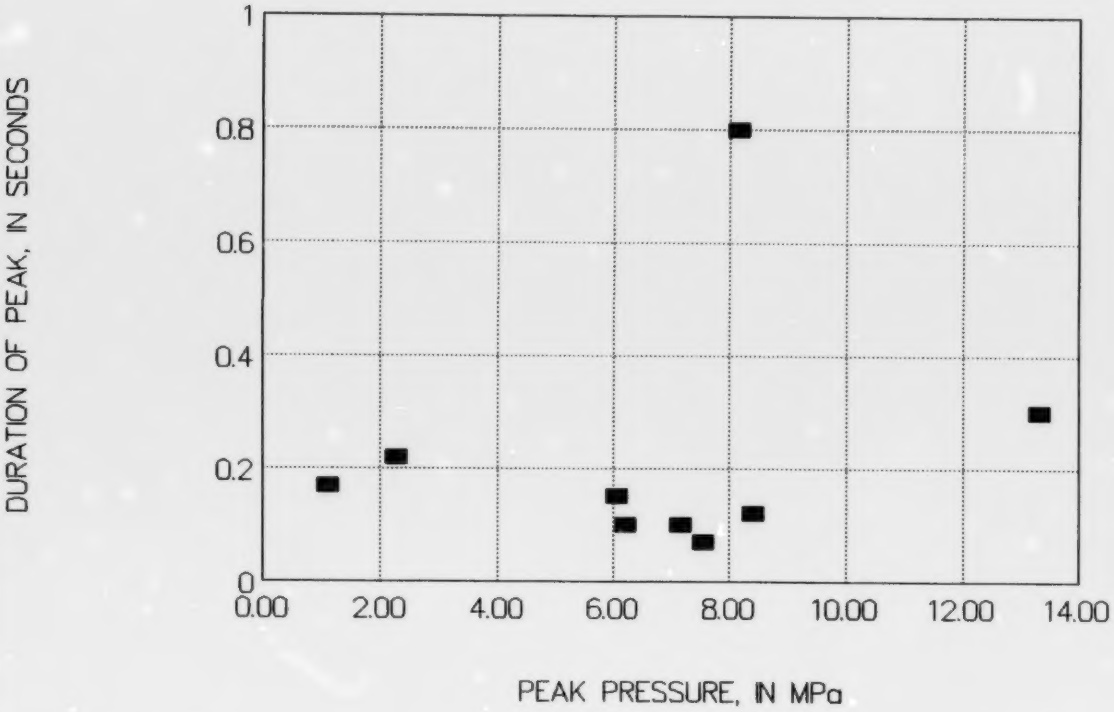
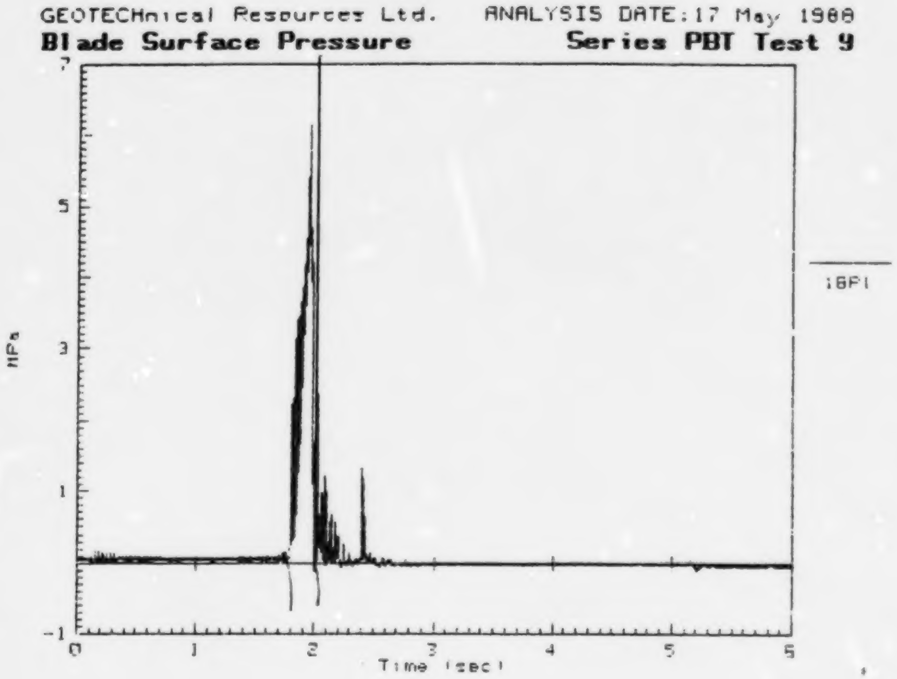
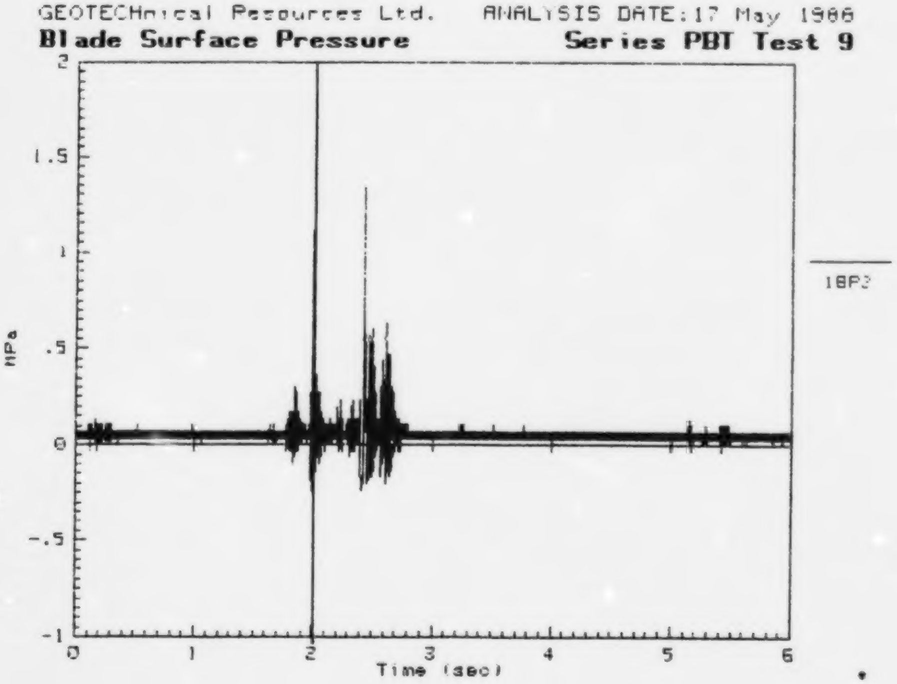


Figure 5.3.17.


GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

Blade Surface Pressure **Series PBT Test 9**


GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

Blade Surface Pressure **Series PBT Test 9**

Figure 5.3.18.

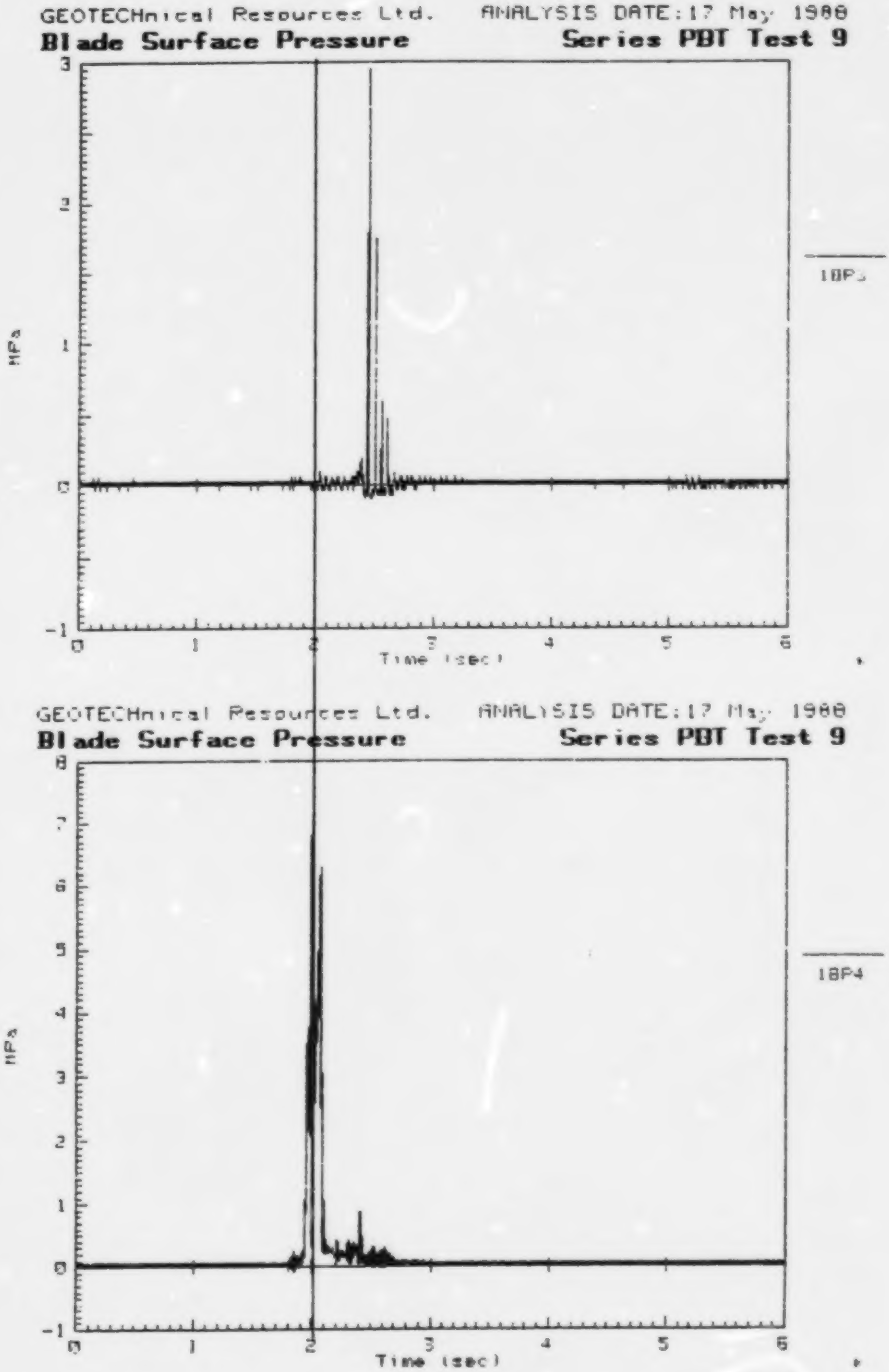

GEOTECHnical Resources Ltd.
ANALYSIS DATE: 17 May 1988
Blade Surface Pressure
Series PBT Test 9
MPa
3
2
1
0
-1
0
1
2
3
4
5
6
Time (sec)
18P3
GEOTECHnical Resources Ltd.
ANALYSIS DATE: 17 May 1988
Blade Surface Pressure
Series PBT Test 9
MPa
8
7
6
5
4
3
2
1
0
-1
0
1
2
3
4
5
6
Time (sec)
18P4

Figure 5.3.19.

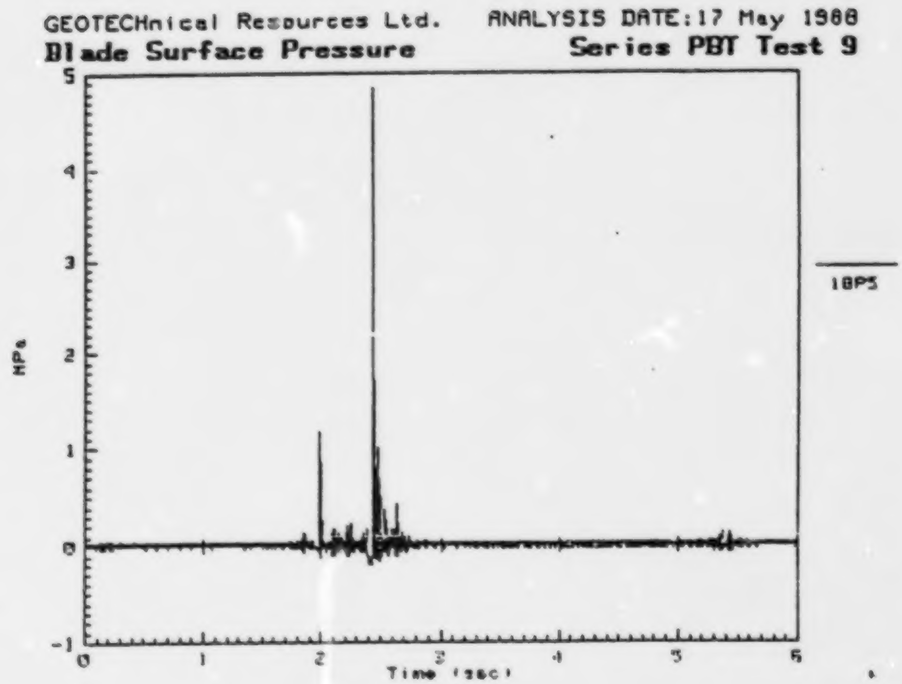
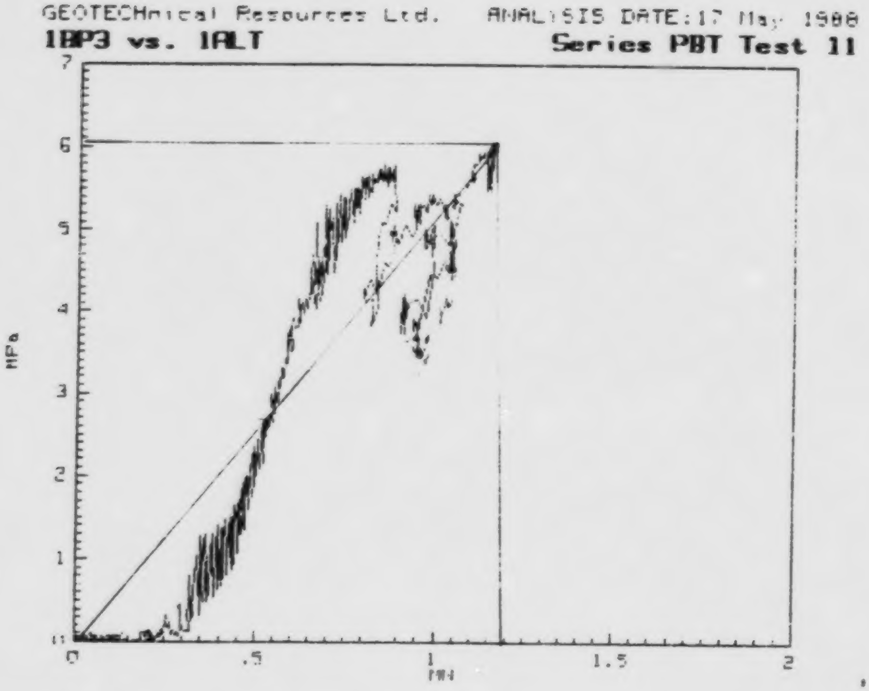

GEOTECHnical Resources Ltd.
ANALYSIS DATE:17 May 1988
Blade Surface Pressure
Series PBT Test 9
MPa
5
4
3
2
1
0
-1
0
1
2
3
4
5
6
Time (sec)
1BPS

Figure 5.3.20.


GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988
1BP3 vs. 1ALT
Series PBT Test 11
MPa
0
1
2
3
4
5
6
7
0
.5
1
1.5
2
MN

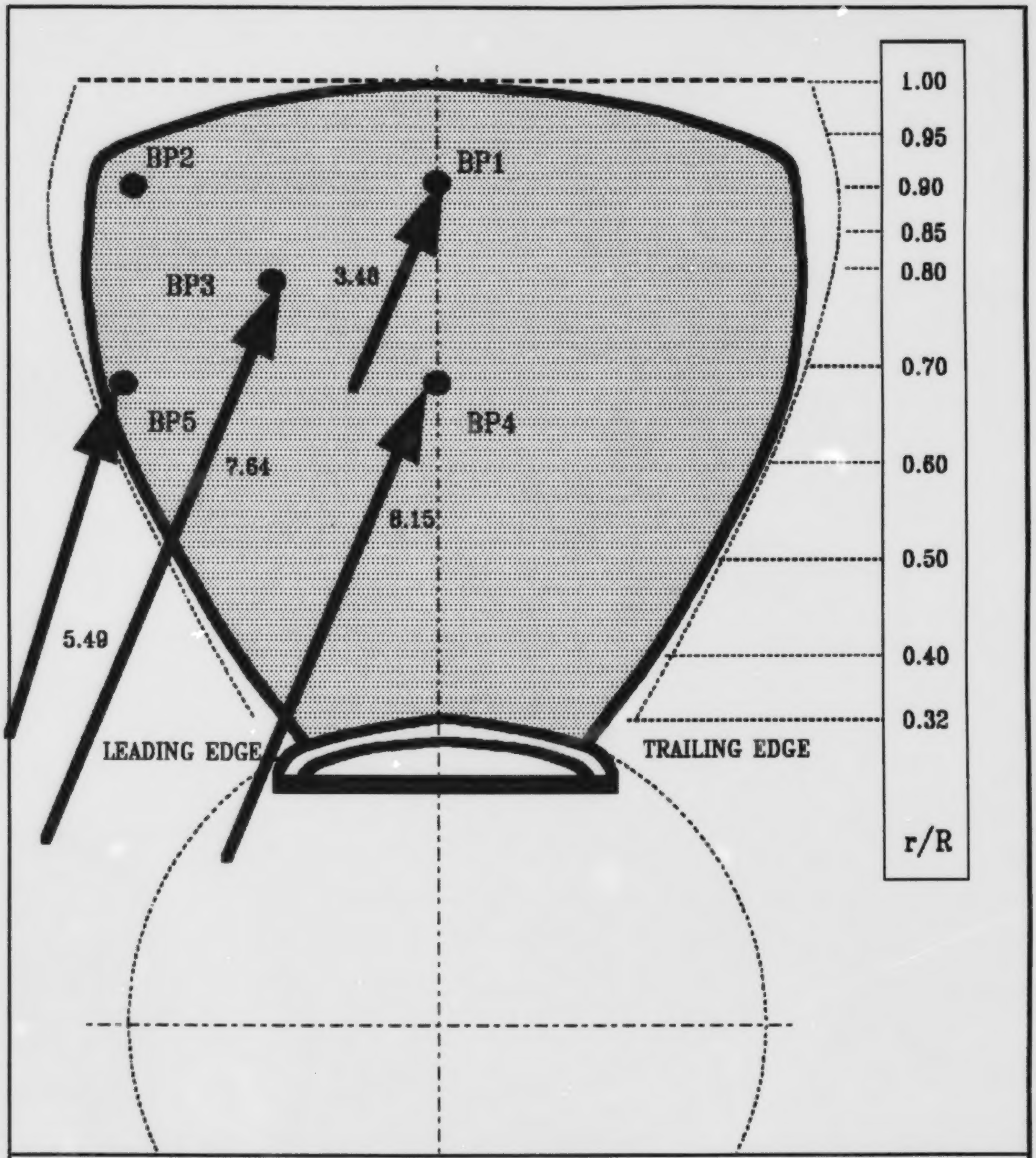

BP2
BP1
BP3
3.48
BP5
BP4
7.64
8.15
5.49
LEADING EDGE
TRAILING EDGE
1.00
0.95
0.90
0.85
0.80
0.70
0.60
0.50
0.40
0.32
r/R

FIGURE TITLE: PRESSURE GAUGE READINGS TEST # 1			
PROJECT NAME: FULL SCALE TESTS ON THE BLADE RESPONSE TO ICE LOADS			
DRAWN BY: VL	CHK'D BY: VL	SCALE: NONE	FIGURE NR: 5.3.21

ARAD

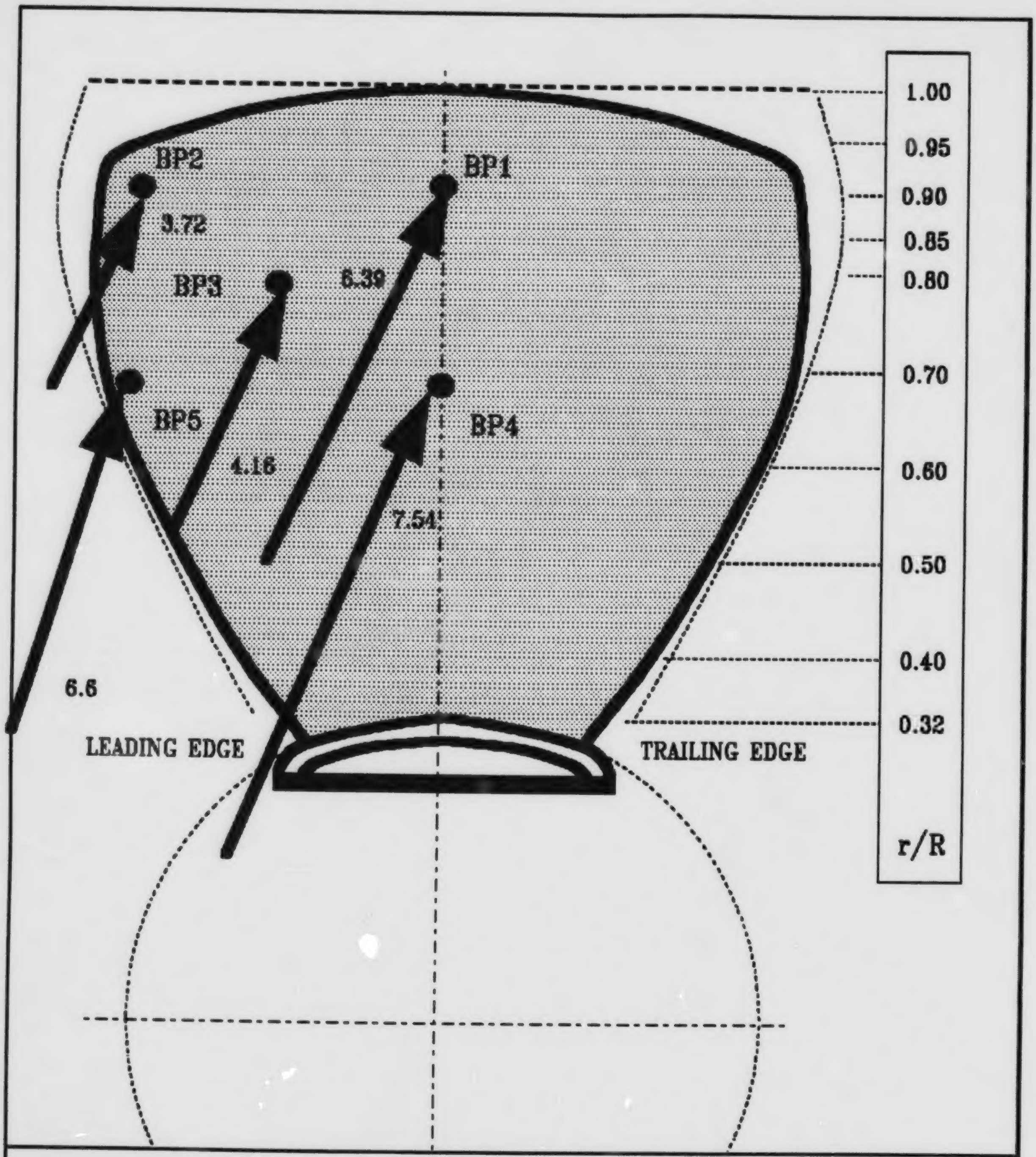

BP2
3.72
BP1
BP3
6.39
BP5
4.16
BP4
7.54
6.6
LEADING EDGE
TRAILING EDGE
1.00
0.95
0.90
0.85
0.80
0.70
0.60
0.50
0.40
0.32
r/R

FIGURE TITLE: PRESSURE GAUGE READINGS TEST # 9

PROJECT NAME: FULL SCALE TESTS ON THE BLADE RESPONSE TO ICE LOADS

DRAWN BY: VL	CHK'D BY: VL	SCALE: NONE	FIGURE NR: 5.3.22

ARAD

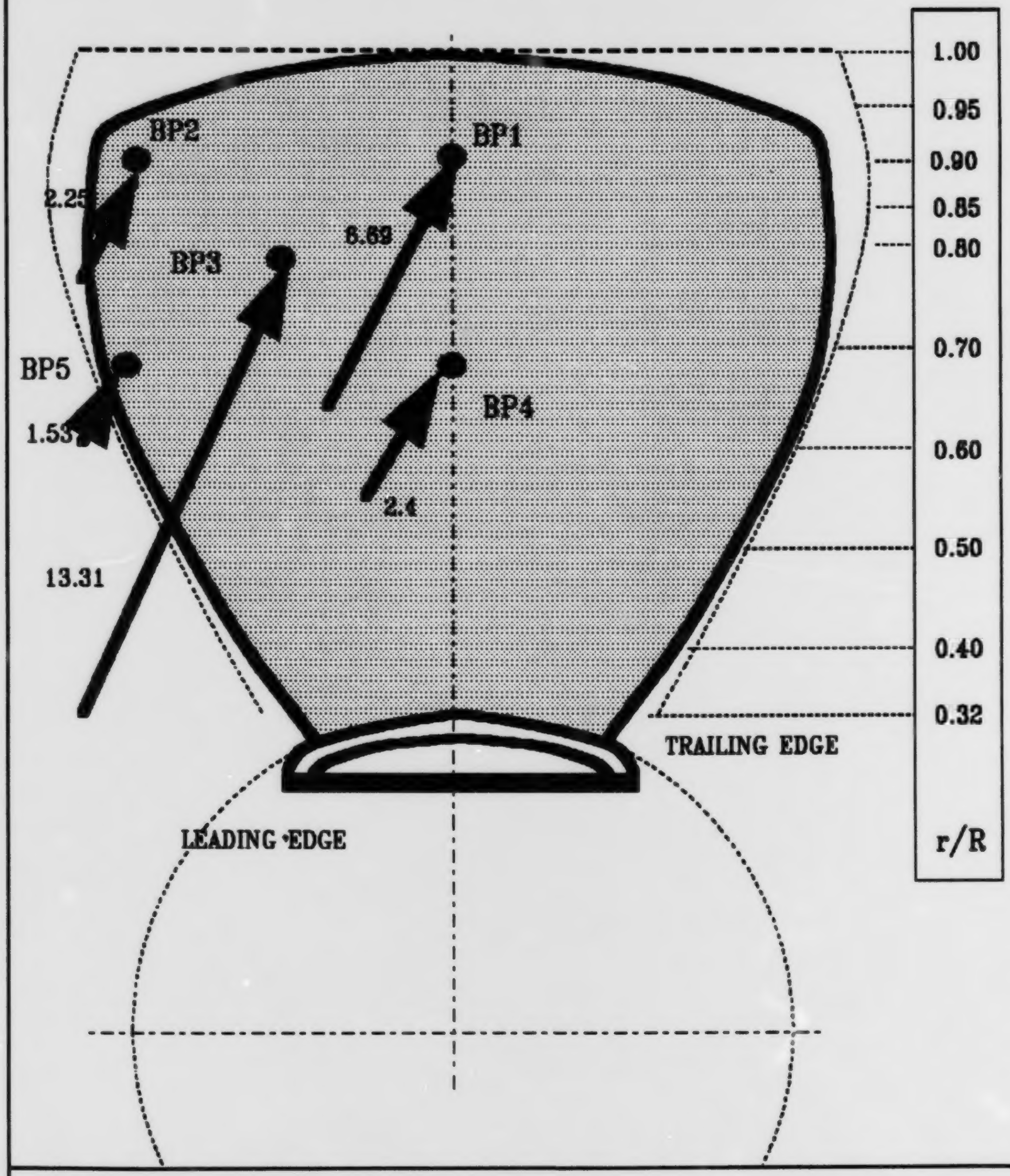

BP1
BP2
BP3
BP4
BP5
2.25
6.69
1.53
2.4
13.31
1.00
0.95
0.90
0.85
0.80
0.70
0.60
0.50
0.40
0.32
r/R
TRAILING EDGE
LEADING EDGE

FIGURE TITLE: PRESSURE GAUGE READINGS TEST #12

PROJECT NAME: FULL SCALE TESTS ON THE BLADE RESPONSE TO ICE LOADS

DRAWN BY: VL	CHK'D BY: VL	SCALE: NONE	FIGURE NR: 5.3.23

ARAD

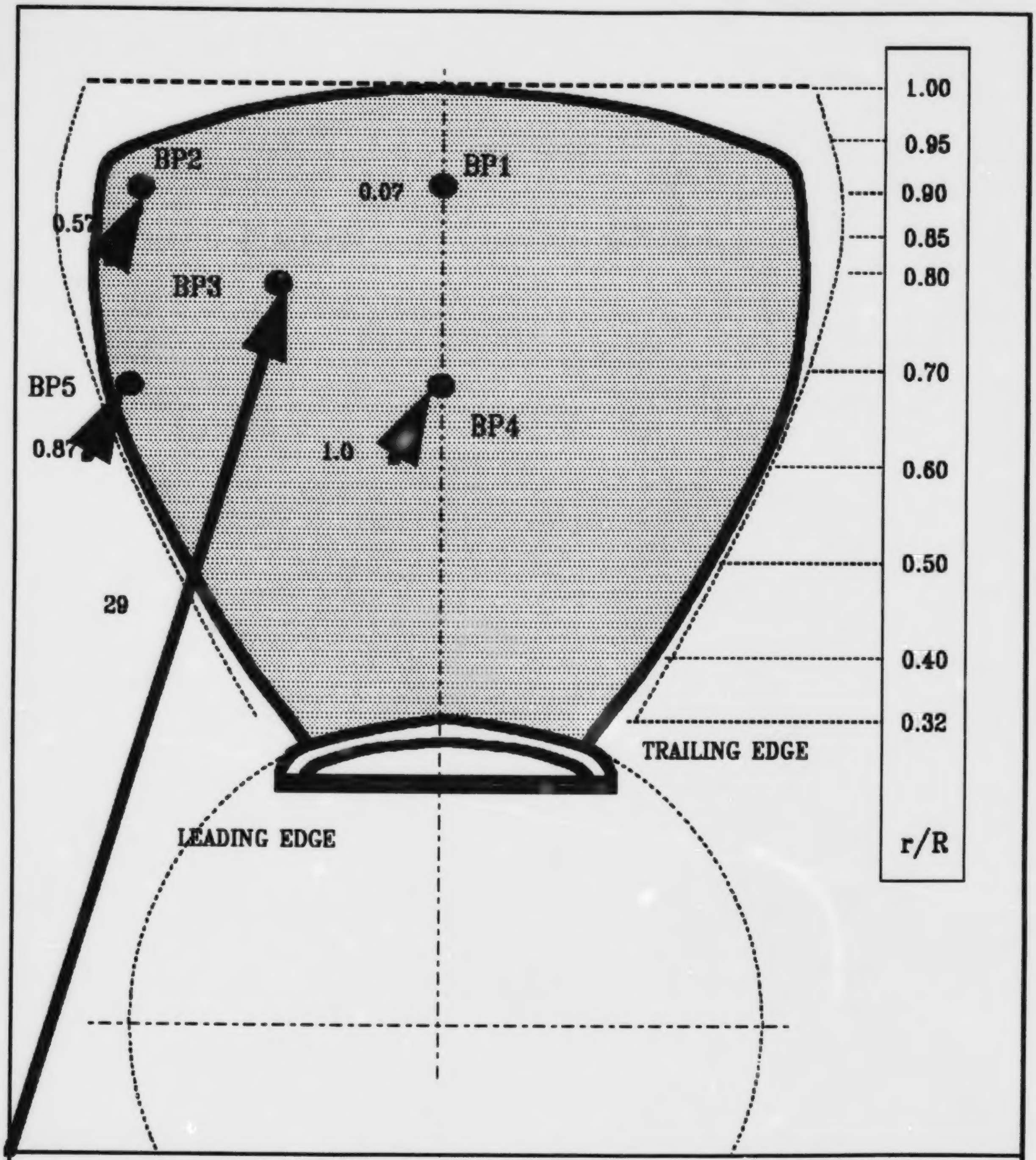

BP2
0.57
BP1
0.07
BP3
BP5
0.87
BP4
1.0
29
1.00
0.95
0.90
0.85
0.80
0.70
0.60
0.50
0.40
0.32
TRAILING EDGE
LEADING EDGE
r/R

FIGURE TITLE: PRESSURE GAUGE READINGS TEST #15

PROJECT NAME: FULL SCALE TESTS ON THE BLADE RESPONSE TO ICE LOADS

DRAWN BY: VL | CHK'D BY: VL | SCALE: NONE | FIGURE NR: 5.3.24

ARAD

5.4. Comparison of the applied loading with the blade strain, stress, and displacement response, both elastic and plastic.

Tests summary

Table 5.4.1 summarizes the load, strains and blade displacement data collected during the tests. Location of the gauges is shown in Figures 4.2a and 4.2.b.

*The maximum load was calculated by adding the three actuators' loads. The distance travelled by the actuators was computed from the first contact point to the moment of the peak load.
The maximum travel needed to reach the peak load (the second peak) was 0.275 m.*

The maximum blade displacement recorded was ***186mm, at BD2.*** *The average OF THE MAXIMUM blade displacements recorded was* ***51.5 mm.*** *The maximum values of the strains recorded was* ***10,000*** *microstrains, well above (five fold) the yield strain of the material, which occurred at BR1, BS3 and BS4.*

When analyzing these numbers, it should be born in mind that the yield strain was exceeded on numerous occasions. A table listing the tests and the gauges recording the above yield strains is given below:

TABLE 5.4.2

Test nr	gauge readings exceeding the yield of the material
14	br1b br2b
15	all except bs1 bs2
18	all except br2a br1c
19	all except br2a br1c

Maximum loads/maximum distance travelled

Figure 5.4.1 shows the correlation of the tests' peak load and the distance travelled by the actuators until the instance of that load, for non-creeping tests. Correlation is poor, for the following reasons:

1. *location of load application was changed during the tests*
2. *size and the shape of the contact area was changing during the tests. Often the large distance traveled was needed before a sizable contact area was developed.*

3 blade gave way to the load to the displacements comparable with the actuators travel.

Maximum loads/blade displacements

Figures 5.4.2, 5.4.3, 5.4.4 show the correlations of the maximum blade displacements and the maximum loads at BD1, BD2 and BD3 respectively, for all the tests except the ones with timber.

The linear relationship between the variables is clear. Strong correlations exist especially for the BD1 and BD3. Correlation coefficients are given in TABLE 5.4.3.

The following observations can be made:

* As expected, the blade at BD2 (near the upper leading edge) displaces the most under the load. The next is BD1 and the last BD3.

* Large scatter of the BD2 is due to the fact that the location of this gauge was changed during the tests.

* The linear dependence of the maximum displacement on the maximum load is valid even when the small plastic deformation of the blade was achieved (run#5).

Figure 5.4.5 shows the interdependence of the blade displacements at the three measurement points, for all the tests. Again, the strong linear correlation of displacements exists at these locations, which proves that knowing the displacements at one point, one can calculate the displacements at the others.

Note that these correlations are valid even though the point of application of the loads has changed substantially during the tests. This proves that:

> the deformations of the blade are not load location sensitive, within the scenarios tested.

The maximum blade displacements were at BD1 for the center load tests 1 to 7, and at BD2 for the rest of the tests.

Maximum loads/maximum strains

Figures 5.4.6 and 5.4.7 show the correlations between the maximum loads and the maximum strains at BS3 and BR1B/BR2B, respectively.

All three locations show strong linear dependence of the maximum strains on the maximum loads, although some scatter exists.

Interdependence of the rosette strains is shown in Figures 5.4.8, 5.4.9 for the BR2, BR1, respectively. Again the linear *relationships are strong, which enables one to calculate the strains in one direction only and to extrapolate the results in the other direction.*

Figures 5.4.10, 5.4.11 show the correlations between the suction and pressure side strains at BS8/BS9 and BR1/BR2 locations, respectively. The following observations are made:

1. *The relationships between the compression and the tension side maximum strains is not linear, for both sets of gauges.*
2. *At BR2/BR1, for moderate strains, the tension stresses are higher than the compression ones. For high strains, the opposite happens.*
3. *At BS8/BS9, for the low strains, the tension side strains are equal to the compression ones, while for the high strains, the tension strains are much higher (30%) than the compression ones.*
4. *Tension strains are the highest at BS8/BS9 while compression ones are the highest at BR1/BR2*

The reasons for this nonlinear and non symmetrical behavior are not understood.

Peak strains distribution on the blade.

For all of the tests except the test #10, the strains at BR1 were the largest in the direction B.

For the tests 1 to 7, most of the maximum strains were encountered at BS3 location, while for the remaining tests BS4 saw the most of the highest strains.

Plastic deformations of the blade

Table 5.4.4 gives details of the plastic deformations recorded during the tests at the positions of the blade displacement gauges. The maximum deformation of 40 mm was recorded at BD2, during the test 15, which also saw the highest average of plastic deformations. Least of deformations were seen at location BD3.

Figures 5.4.12, 5.4.13, 5.4.14 show the magnitude of the residual plastic deformations as functions of maximum displacements during the tests for the BD1, BD2 and BD3 locations. Fig 5.4.15 shows all 3 blade displacement locations for comparison.

The following observations can be made:

BD1

1. *Small plastic deformations are visible already at the peak displacements above 20mm, at all locations. The nature of these deformations is probably due to the local plasticity of small areas adjacent to the gauges.*

2. *Large plastic deformation was registered at the peak displacement of 98 mm, which is due to the global plastic deformation of the blade segment.*

BD2

1. *No significant plastic deformation takes place until the peak displacement reaches a magnitude of 57mm.*

2. *The maximum plastic deformation of 40mm was registered after the peak displacement of 74mm.*

BD3

1. *Small plastic deformations are already visible at 5mm of peak displacement.*

2. *The maximum plastic deformation of 10 mm was registered after the peak displacement of 33 mm.*

The comparison between the deformations at different locations leads to the conclusion that:

At BD2, the material behaves as linear elastic-plastic material with little residual strain at low and moderate displacements.

At other locations, the material exhibits non linear plastic behavior already at low strains. These locations have thicker sections than BD2.

Blade stresses

Exact determination of the principal stresses using the rosette strains can be done using the following equations:

$$s1 = E/2 * \{(ea+ec)/(1-m) + ((ea-ec)^2 + (2eb-ea-ec)^2)^{0.5}\} \quad ..5.4.1$$
$$s2 = E/2 * \{(ea+ec)/(1-m) - ((ea-ec)^2 + (2eb-ea-ec)^2)^{0.5}\} \quad ..5.4.2$$

where:

ea, eb and ec are the strains at the gauges a,b,c respectively,
m is the Poisson ratio, taken as 0.3 for the CUNIAL, and
E is the modulus of elasticity of the material, taken as 130 GPa.

The above equation applies only to the elastic (linear) range of the material stress- strain curve, so the computed values have ***only comparative character in the post - elastic range.***

Table 5.4.5 shows the results of computations of the surface principal stresses at the rosette gauge locations. Following are the main observations:

1. ***The maximum reference principal stress was recorded during*** *the test# 19,at the compression side.*

2. *Tension side stresses were of a comparable magnitude and often larger than the compression stresses.*

3. *Yielding of the material begun when the principal stress* ***exceeded 251 MPa,*** *which is very close to the design yield point of 245 MPa.*

Figure 5.4.16 shows the peak principal stress computed using the above formula versus the peak load recorded during the tests, for both tension and compression sides. The nonlinear relationship is apparent.

Table 5.4.6 shows the stresses computed for the uniaxial strain gauge locations using the uniaxial stress field relationship:

*sigma = su * E....................................5.4.3*

where su is the uniaxial strain obtained from the gauge readings.

The stresses in the post elastic domain were computed using the relationship noted in Figure 3.11.

The following observations can be made:

1. *The maximum and the minimum plastic stresses recorded were 290 MPa (45% of the UTS).*

2. *The minimum (compression) stresses recorded were at the gauge locations BS3, BS4 and the maximum (tension) were at BS9.*

Figures 5.4.17, 5.4.18 and 5.4.19 show as examples the maximum displacement distributions during the tests #1, 9 and 18, respectively.

Figures 5.4.20 and 5.4.21 show the distribution of maximum strains on the compression side during the tests #1 and 19, respectively.

Figure 5.4.22 and 5.4.23 show the maximum strain distributions on the tension side during the tests #1 and #19.

Conclusions:

1. There is no correlation between the magnitude of the peak load and the distance travelled during the indentation, for the conditions tested.

2. There is a linear, strong correlation between the maximum load and the maximum blade displacement. The blade can be modeled as a linear "spring".

3. Under the conditions tested, the maximum blade displacement was recorded at the upper corner near the leading edge (BD2), and was of the magnitude of **186 mm**.

4. Blade displacements distribution show strong interdependence, which means that the blade elements distribute and share the load.

5. When loaded symmetrically, the maximum deformations recorded were at the tip of the blade.

6. Strong linear correlation exists between the maximum blade loads and the maximum strains recorded. The maximum strain recorded were **0.01 strains,** in a number of locations.

7. The relationship between the compression and tension side strains is non-linear.

8. For high strains, the compression stresses are higher than the tension side strains, while for the moderate strains the opposite is true. This is valid for the BR gauges location.

9. Near the leading edge (BS8/BS9) for the high strains the tension strains are much higher than the compression ones.

10. At the location of the BR gauges, most of the high strains recorded were in the direction B (along the blade axis).

11. The maximum plastic deformation recorded was **40mm,** at BD2.

12. At the center of the blade (BD1) displacements of **20 mm** result in small plastic deformations.

13. At the leading edge, displacements of the order of **57mm** are needed to cause the plastic deformations.

14. Towards the root of the blade(BD3) plastic deformations occur already at displacements of the order of **5mm**.

15. The material of the blade behaves as a linear elasto-plastic material at the location BD2 (thin sections) while at the thick sections the material the behavior is as a nonlinear elasto-plastic material already at low strain levels. This is consistent with the thickness/yield strain

characteristics of the blade material.

16. *The maximum and the minimum stresses computed using the uniaxial stress/strain relationship were:*

    ***+290 MPa** and*
    ***-290 MPa**, respectively*

17. *At the stress level of 200 MPa, plastic flow of the material was registered.*

18. *There is a nonlinear dependence of the peak principal stress and the peak load registered during the tests.*

19. *Under the conditions tested, the strains at the location BS4, were of the highest magnitude, which confirms the results of the blade/cantilever beam model.*

20. *The minimum plastic domain stresses occurred at the gauge locations BS3, BS4 and the maximum at the location BS9.*

TABLE 5.4.1

SUMMARY OF DISPLACEMENTS AND STRAINS

TEST NR	TIME TO MAX LOAD	ADVANCE SPEED MM/S	DIST TRAVELL TO PEAK	MAX LOAD MN	MAXIMUM DISPLACEMEN			MAX BLADE STRAINS			MINIMUM VALUE TESTWISE	BR2A	BR2B	BR2C	MAXIMUM VALUE TESTWIS	BS1	BS2	BS3	BS4	BS5	BS6	BS7	BS8	MINIMUM VALUE TESTWISE	BS9	MAXIMUM VALUE TESTWIS
					BD1	BD2	BD3	BR1A	BR1B	BR1C																
					MILIMETERS			MICROSTRAINS								MICROSTRAINS										
1	3	91.5	0.275	0.66	(15.0)	(11.0)	(7.0)		(510)		(510)		820		820	(320)		(530)	(315)	(530)	(365)	(190)	(285)	-530	725	725
2	0.45	85.7	0.039	0.53	(14.2)	(12.7)	(5.0)	(520)	(710)	(185)	(710)		840		840	(380)		(690)	(660)	(600)	(660)	(435)	(520)	-690	655	655
3	0.3	83.3	0.025	0.53	(16.0)	(14.0)	(5.0)	(560)	(770)	(210)	(770)		900		900	(500)		(770)	(690)	(640)	(710)	(455)	(560)	-770	590	590
4	2.2	100.0	0.220	1.03	(21.5)	(15.0)	(8.0)	(600)	(1,200)	(500)	(1,200)		350		350	(505)		(1,080)	(255)	(960)	(280)	(175)	(220)	-1080	230	230
5	1.7	100.0	0.170	0.37	(9.6)	(9.0)	(4.0)	(330)	(450)	(130)	(450)		240		240	115	(190)	(365)	(440)	(360)	(450)	(265)	(145)	-450	125	125
6	1	101.5	0.102	0.57	(13.0)	(10.5)	(3.4)	(250)	(360)	(220)	(360)		720		720	(70)		(480)	(195)	(480)	(265)	(135)	(207)	-480	202	202
7	2.1	102.7	0.216	0.37	(12.0)	(9.5)	(4.3)	(390)	(460)	(90)	(460)		600		600	(206)		(520)	(590)	(410)	(500)	(400)	(400)	-590	440	440
8	0.45	100.0	0.045	0.53	(15.0)	(30.0)	(5.6)	(600)	(740)	(120)	(740)	630	903	194	903	(363)	(840)	(710)	(920)			(670)	(660)	-920	675	675
9	0.75	100.7	0.076	1.28	(29.0)	(93.0)	(11.0)	(1,260)	(1,400)	(400)	(1,400)	420	1,700	1,360	1,700	(810)	(785)	(1,100)	(1,800)			(1,700)	(1,500)	-1800	1,505	1505
10	0.3	102.9	0.031	0.42	(11.0)	(30.4)	(4.0)	(645)	(560)	30	(645)					(37)	(820)	(355)				(990)	(785)	-990	735	735
11	0.75	100.7	0.076	1.13	(28.5)	(57.2)	(10.3)	(1,240)	(1,440)	(230)	(1,440)	300	1,800	0	1,800	(585)	(1,505)	(1,260)	(2,120)			(1,700)	(1,520)	-2120	1,550	1550
12	1.2	100.7	0.121	1.27	(30.5)	(50.3)	(11.0)	(1,350)	(1,630)	(350)	(1,630)	350	1,970	1,450	1,970	(710)	(820)	(1,400)	(2,000)			(1,540)	(1,520)	-2000	1,550	1550
14	20.5	3.0	0.061	1.75	(40.4)	(57.0)	(15.0)	(1,700)	(2,300)	(570)	(2,300)	625	2,800	1,950	2,800	(472)	(700)	(1,690)	(2,020)			(1,540)	(2,050)	-2050	1,995	1995
15	40	5.5	0.218	3.93	(97.0)	(78.0)	(33.0)	(4,800)	(4,000)	(2,750)	(4,800)	2,780	4,800	4,600	4,800	(450)	(440)	(3,250)	(3,900)			(4,050)	(5,000)	-5000	4,800	4800
18	2.1	103.5	0.217	2.05	(80.0)	(160.0)	(21.5)	(3,100)	(4,300)	(1,100)	(4,300)	318	5,150	5,850	5,850	(3,000)	(4,100)	(8,100)	(10,000)			(8,000)	(4,400)	-10000	6,000	6000
19	2.4	102.7	0.246	2.40	(93.0)	(186.0)	(25.0)	(4,700)	(10,000)	(2,050)	(10,000)	320	7,700	5,500	7,700	(5,900)	(4,400)	(10,000)	(10,000)			(8,100)	(6,500)	-10000	10,000	10000
MAX		103.5	0.275	3.93	-9.6	-9	-3.4	-250	-360	30		2780	7700	5850		115	-190	-355	-195	-360	-265	-135	-145		10000	
MIN		3	0.025	0.37	-97	-186	-33	-4800	-10000	-2750		300	240	0		-5900	-4400	-10000	-10000	-960	-710	-8100	-6500		125	
AVGE		86.522	0.134	1.18	-32.9	-51.48	-10.8	-1470	-1926.9	-591.7		717.9	2086.2	2613		-887.06	-1460	-2018.8	-2393.7	-569	-461	-1897	-1642		1986.1	

Figure 5.4.1.

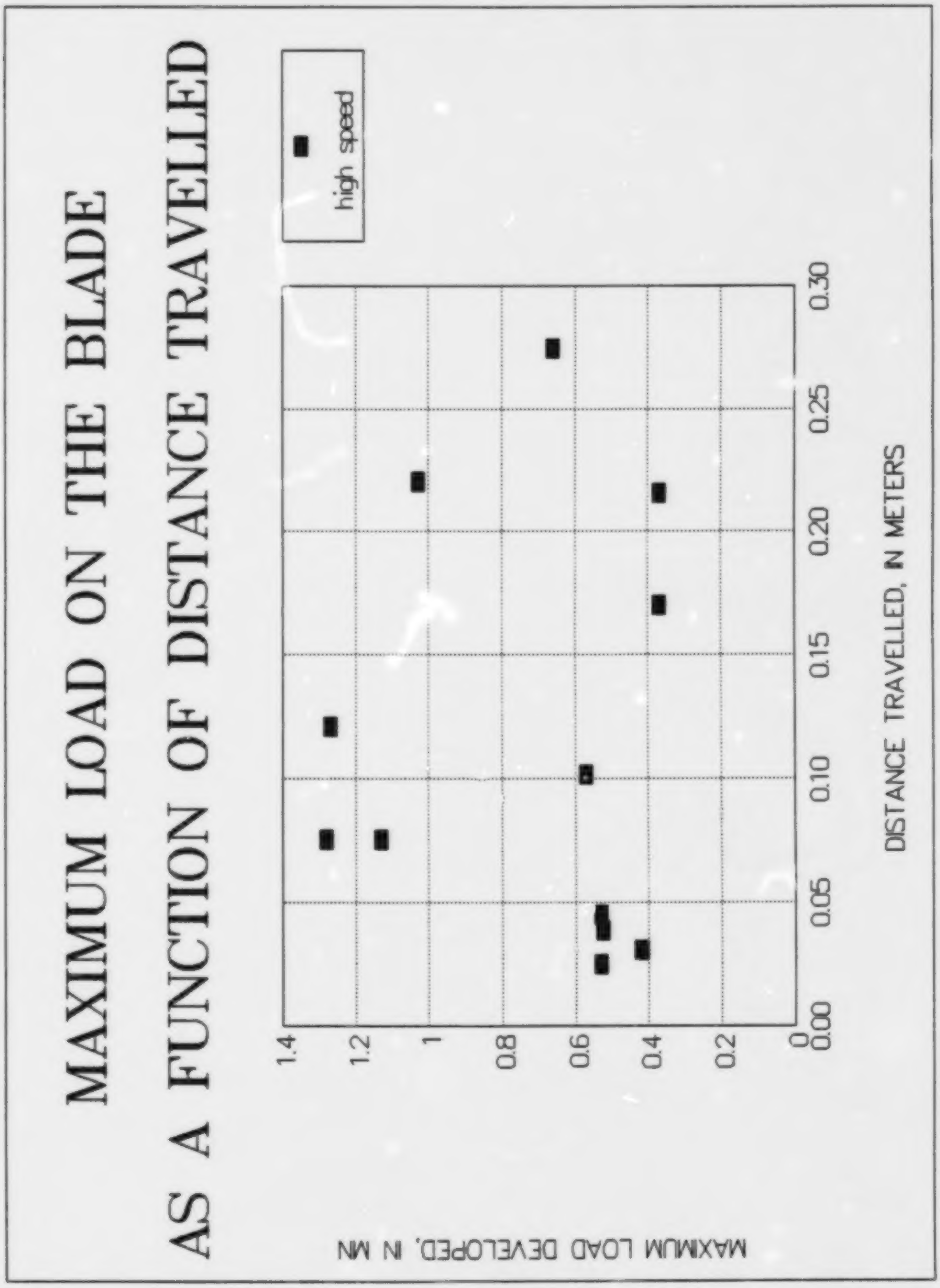
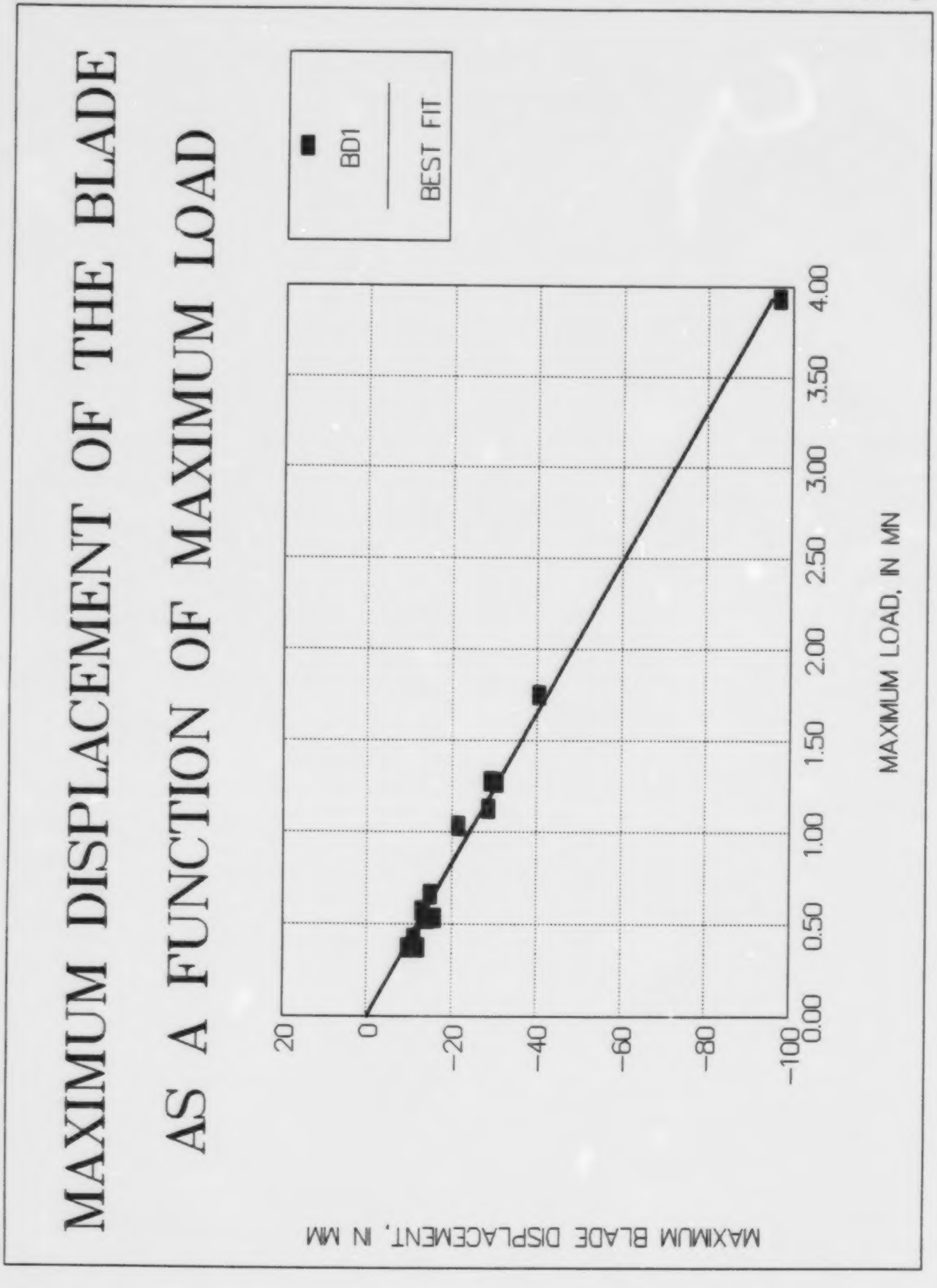

MAXIMUM LOAD ON THE BLADE
AS A FUNCTION OF DISTANCE TRAVELLED
high speed
MAXIMUM LOAD DEVELOPED, IN MN
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.00
0.05
0.10
0.15
0.20
0.25
0.30
DISTANCE TRAVELLED, IN METERS

FIGURE 5.4. 2



MAXIMUM DISPLACEMENT OF THE BLADE AS A FUNCTION OF MAXIMUM LOAD

FIGURE 5.4. 3

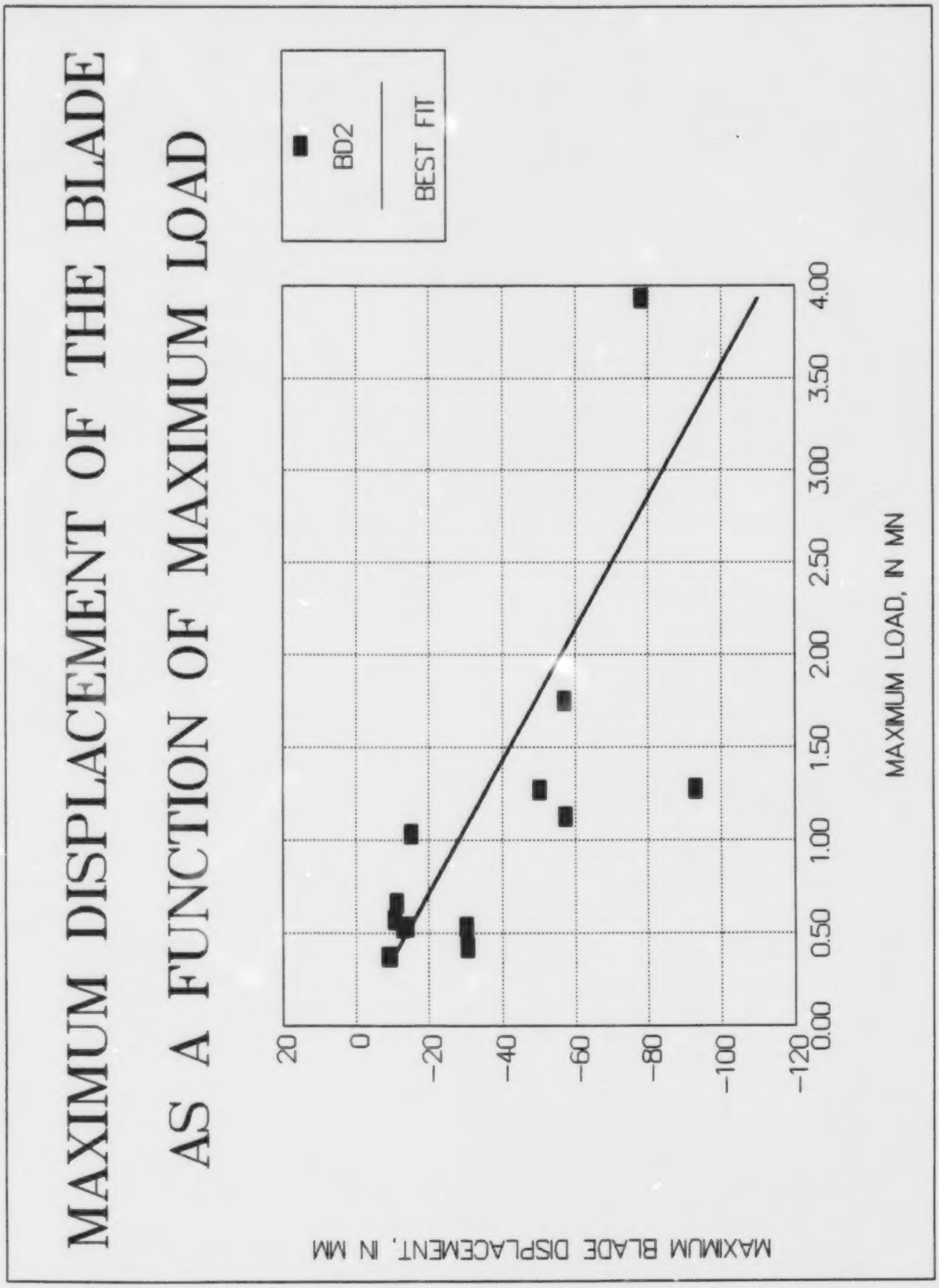

MAXIMUM DISPLACEMENT OF THE BLADE AS A FUNCTION OF MAXIMUM LOAD

FIGURE 5.4. 4

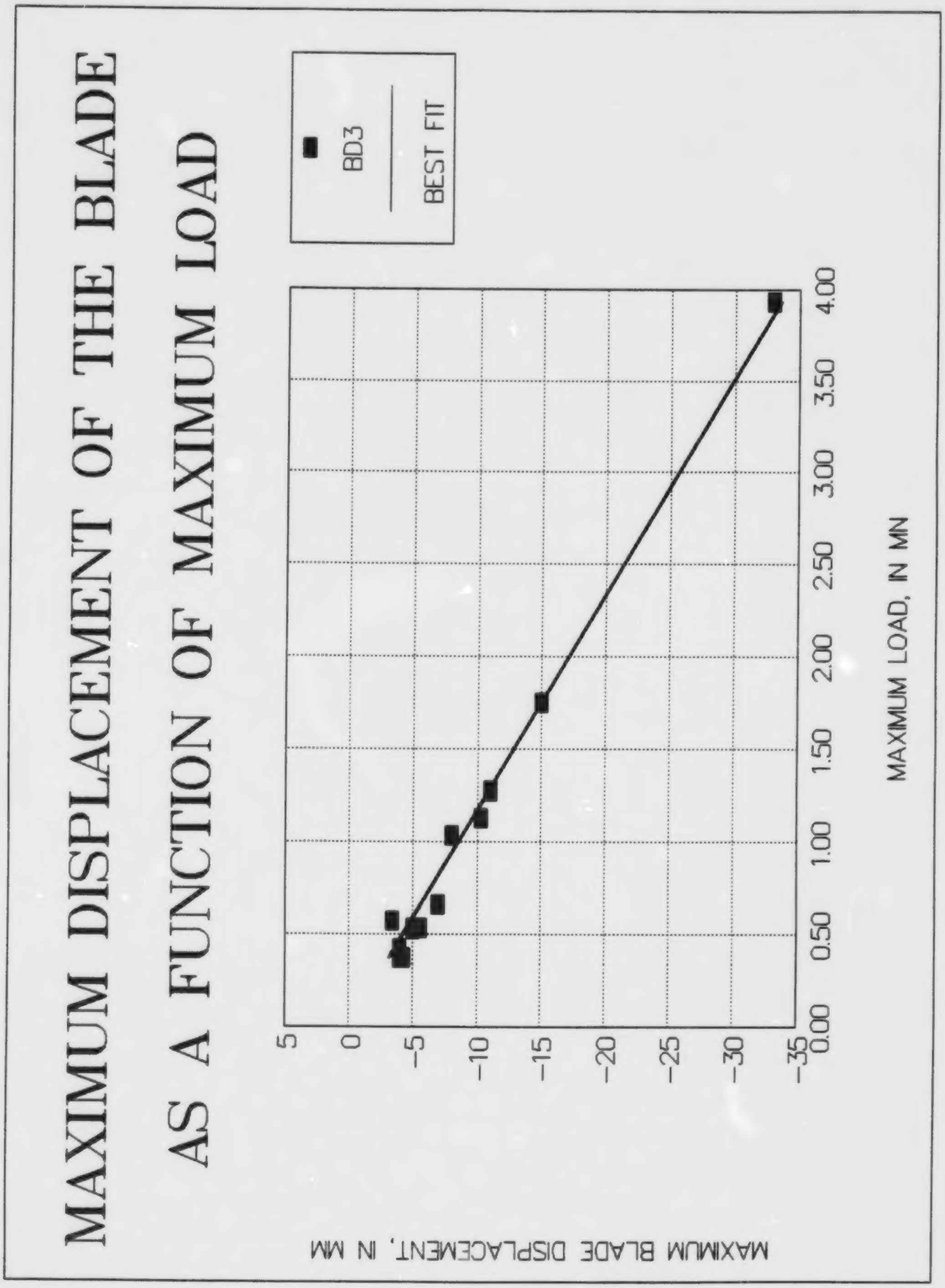

MAXIMUM DISPLACEMENT OF THE BLADE AS A FUNCTION OF MAXIMUM LOAD

TABLE. 5.4.3.
REGRESSION ..ESULTS DISPLACEMENT/ MAXIMUM LOAD

REGRESSION DISPLACEMENT BD1/ MAX LOAD

```
       Regression Output:
Constant                                 0
Std Err of Y Est                    2.0196
R Squared                            0.992
No. of Observations                     14
Degrees of Freedom                      13

X Coefficient(s)       -24.323
Std Err of Coef.       0.39499
```

REGRESSION DISPLACEMENT BD2/ MAX LOAD

```
       Regression Output:
Constant                                 0
Std Err of Y Est                    21.644
R Squared                           0.4087
No. of Observations                     14
Degrees of Freedom                      13

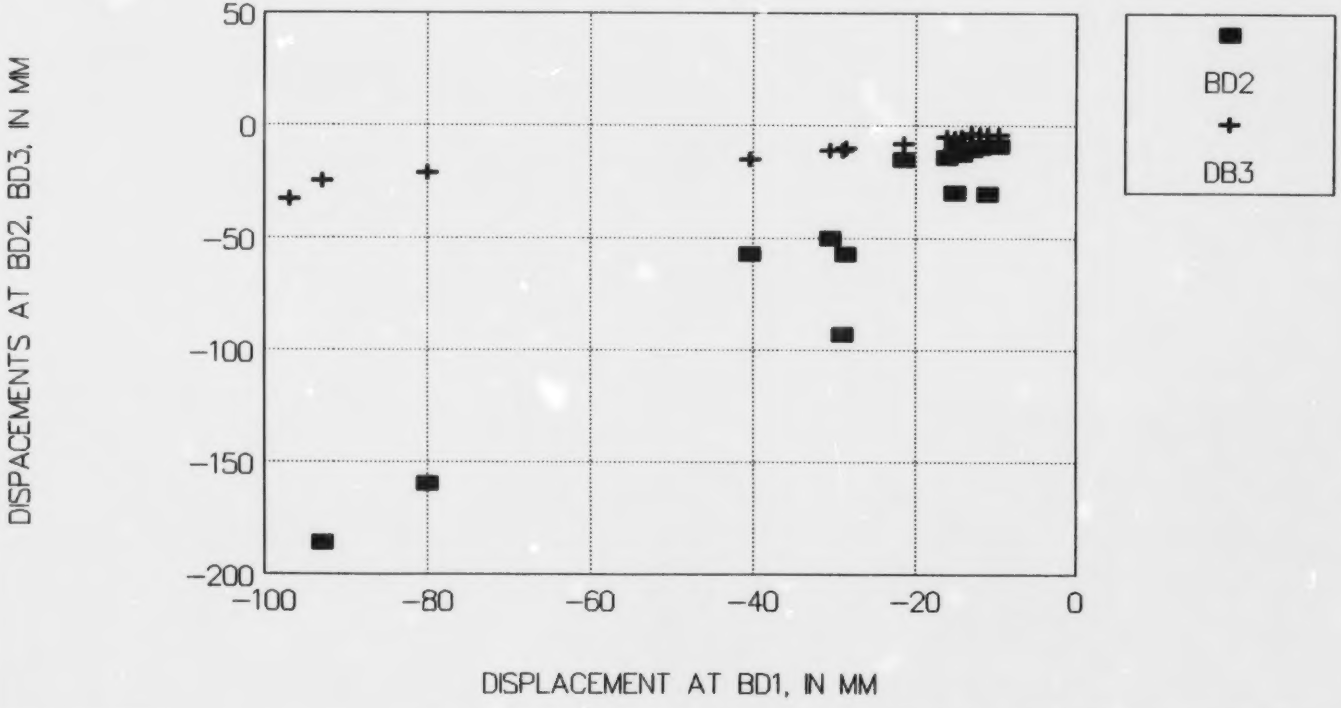
X Coefficient(s)       -28.004
Std Err of Coef.       4.23307
```

REGRESSION DISPLACEMENT BD3/ MAX LOAD

```
Std ErrRegression Output:           0.9959
Constant                                 0
Std Err of Y Est                     0.843
R Squared                           0.9881
No. of Observations                     14
Degrees of Freedom                      13

X Coefficient(s)       -8.5456
Std Err of Coef.       0.16486
```

FIGURE 5.4. 5



MAXIMUM BLADE DISPLACEMENTS CORRELATIONS BETWEEN THE GAUGES

Figure 5.4.6.

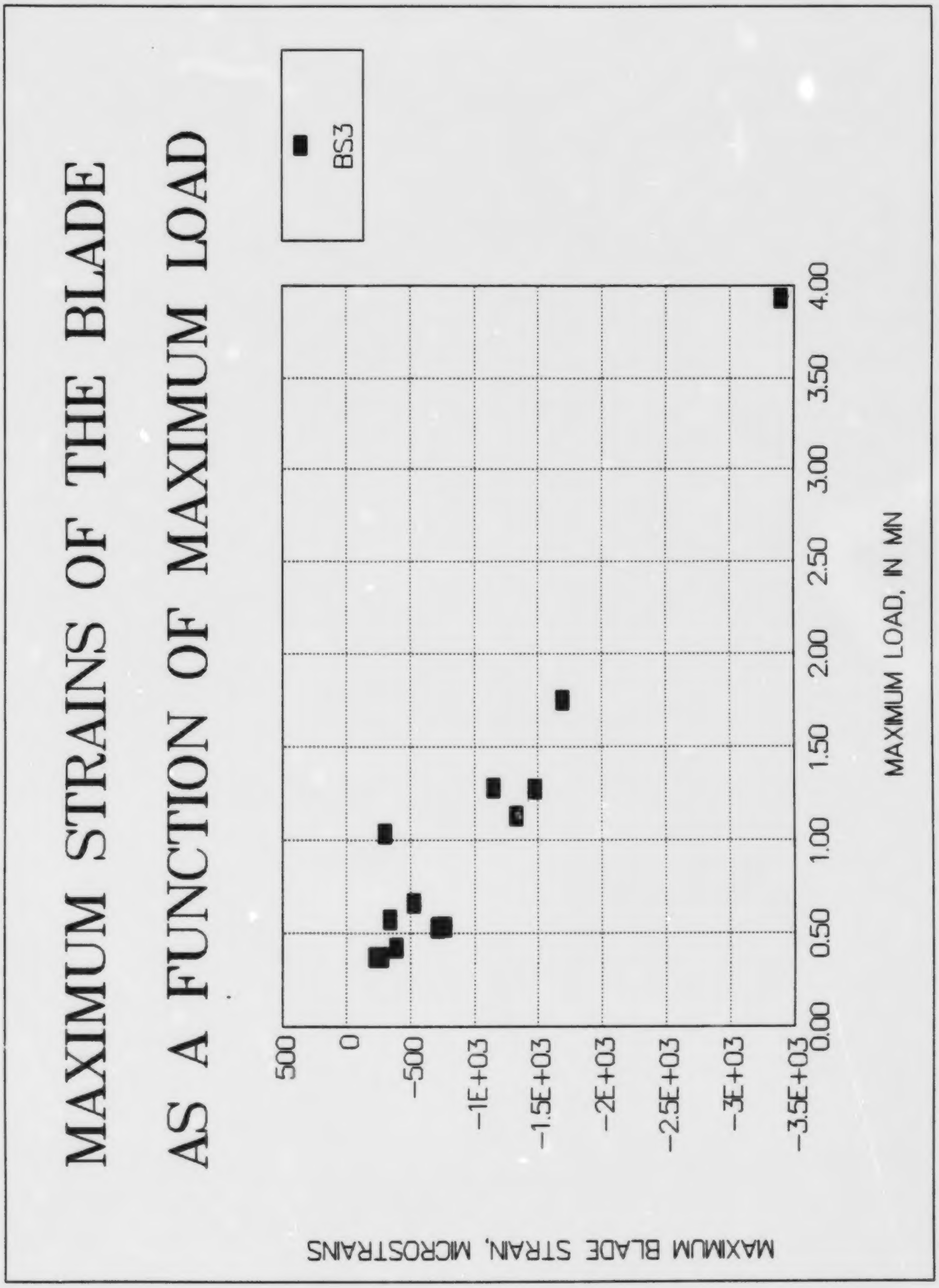

MAXIMUM STRAINS OF THE BLADE
AS A FUNCTION OF MAXIMUM LOAD
BS3
MAXIMUM BLADE STRAIN, MICROSTRAINS
500
0
-500
-1E+03
-1.5E+03
-2E+03
-2.5E+03
-3E+03
-3.5E+03
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
MAXIMUM LOAD, IN MN

Figure 5.4.7.

MAXIMUM STRAINS OF THE BLADE AS A FUNCTION OF MAXIMUM LOAD

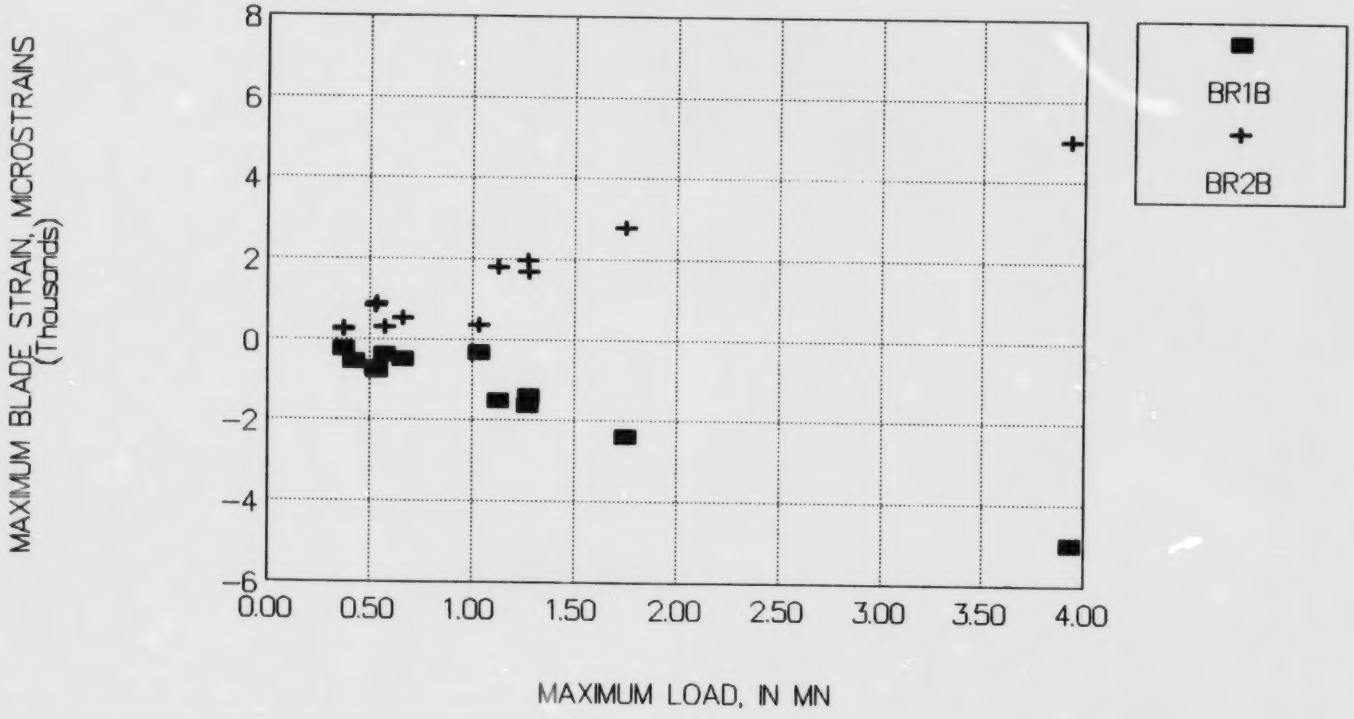
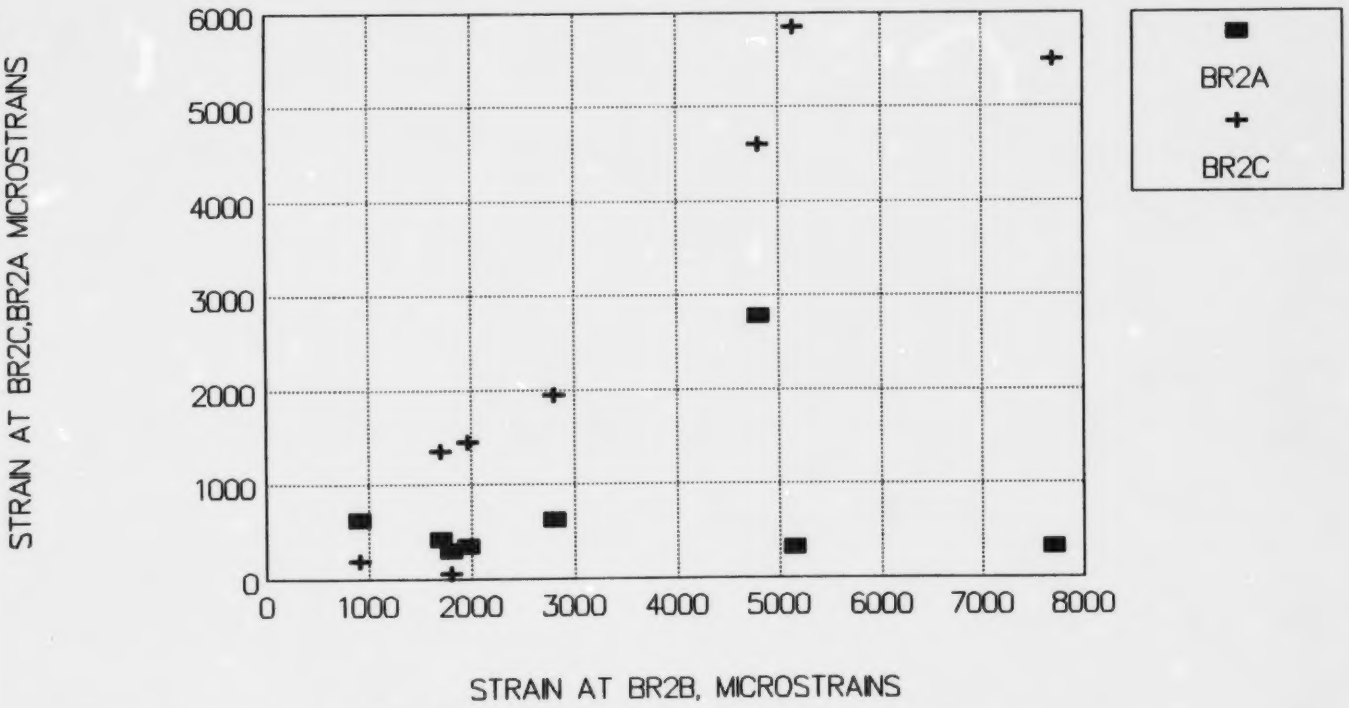
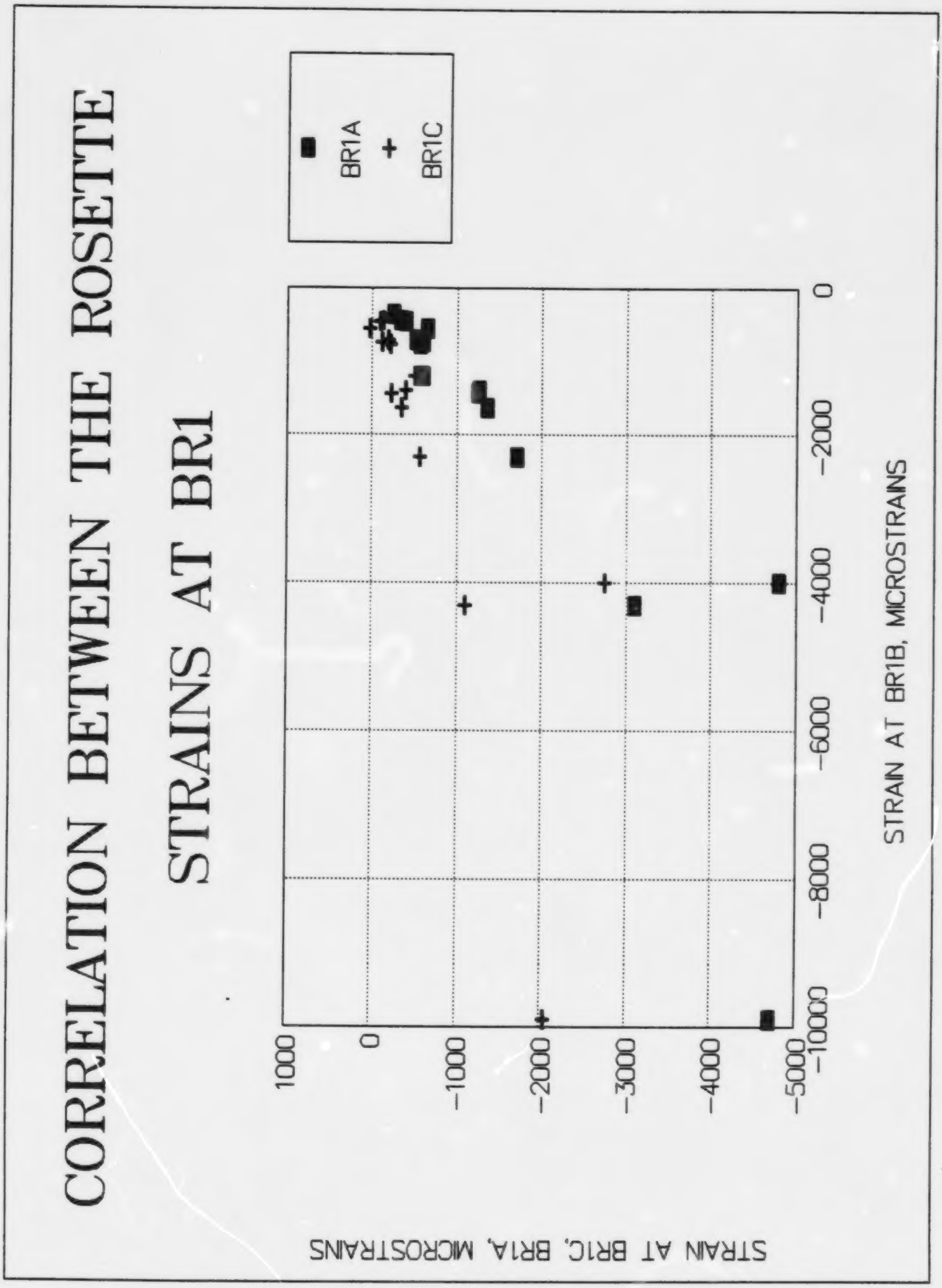


Figure 5.4.8.



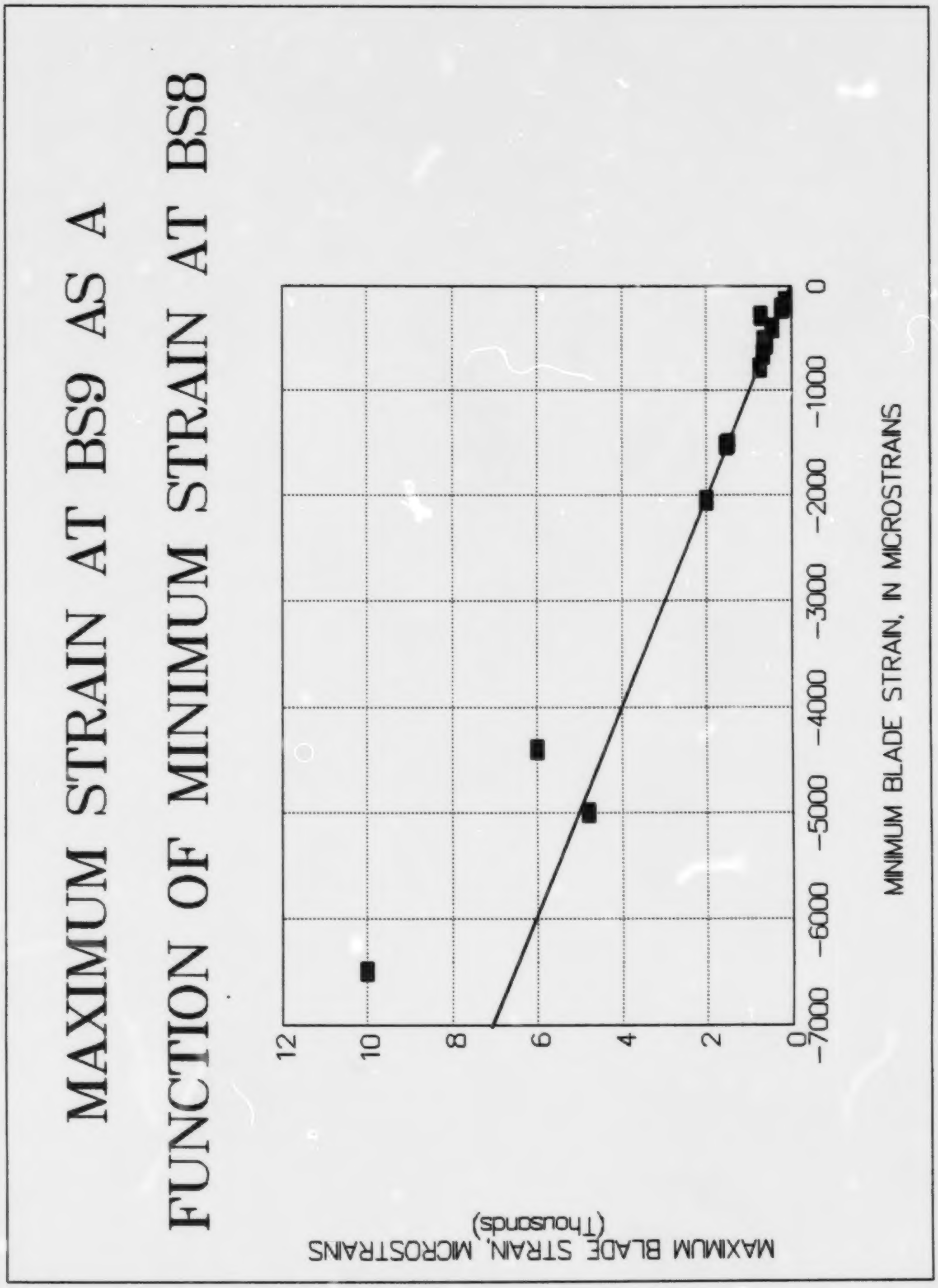
CORRELATION BETWEEN THE ROSETTE STRAINS AT BR2

Figure 5.4.9.



CORRELATION BETWEEN THE ROSETTE STRAINS AT BR1

Figure 5.4.10.



MAXIMUM STRAIN AT BS9 AS A FUNCTION OF MINIMUM STRAIN AT BS8

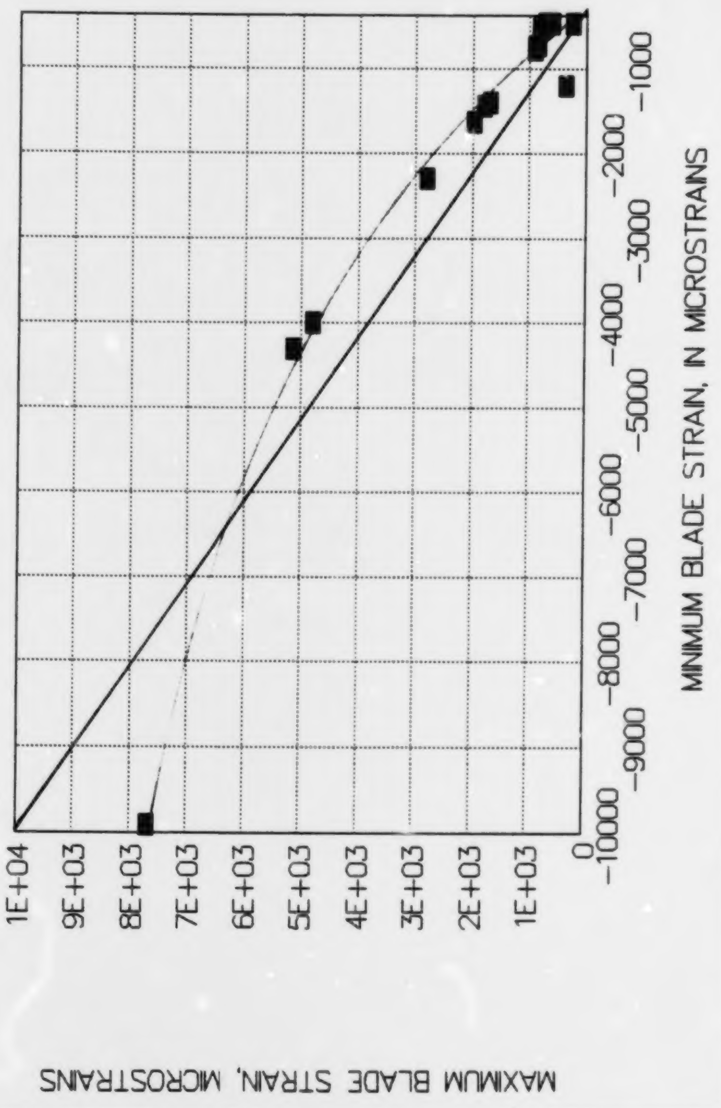

MAXIMUM STRAINS AT BR2 AS A FUNCTION OF MINIMUM STRAINS AT BR1

TABLE *5.4.4*

PEAK AND RESIDUAL PLASTIC DEFORMATIONS

TEST NR	MAX LOAD MN	MAXIMUM DISPLACEMENTs, in milimeters					
		BD1		BD2		BD3	
		peak	plastic	peak	plastic	peak	plastic
1	0.66	(15.0)	0.0	(11.0)	0.0	(7.0)	0.0
2	0.53	(14.2)	0.2	(12.7)	0.2	(5.0)	0.0
3	0.53	(16.0)	0.0	(14.0)	0.1	(5.0)	0.0
4	1.03	(21.5)	0.0	(15.0)	0.0	(8.0)	0.0
5	0.37	(9.6)	0.0	(9.0)	0.0	(4.0)	0.0
6	0.57	(13.0)	0.0	(10.5)	0.0	(3.4)	0.0
7	0.37	(12.0)	0.0	(9.5)	0.0	(4.3)	0.0
8	0.53	(15.0)	0.0	(30.0)	0.0	(5.6)	0.0
9	1.28	(29.0)	2.0	(93.0)	0.0	(11.0)	0.7
10	0.42	(11.0)	0.5	(30.4)	1.5	(4.0)	0.5
11	1.13	(28.5)	0.3	(57.2)	0.3	(10.3)	0.3
12	1.27	(30.5)	0.0	(50.3)	0.0	(11.0)	0.0
14	1.75	(40.4)	1.2	(57.0)	1.2	(15.0)	1.2
15	3.93	(97.0)	28.0	(78.0)	40.0	(33.0)	10.0
MAX	3.93	(9.60)	28.00	(9.00)	40.00	(3.40)	10.00
MIN	0.37	(97.00)	0.00	(93.00)	0.00	(33.00)	0.00
AVGE	1.03	(25.19)	2.30	(34.11)	3.09	(9.04)	0.91

FIGURE 5.4.12

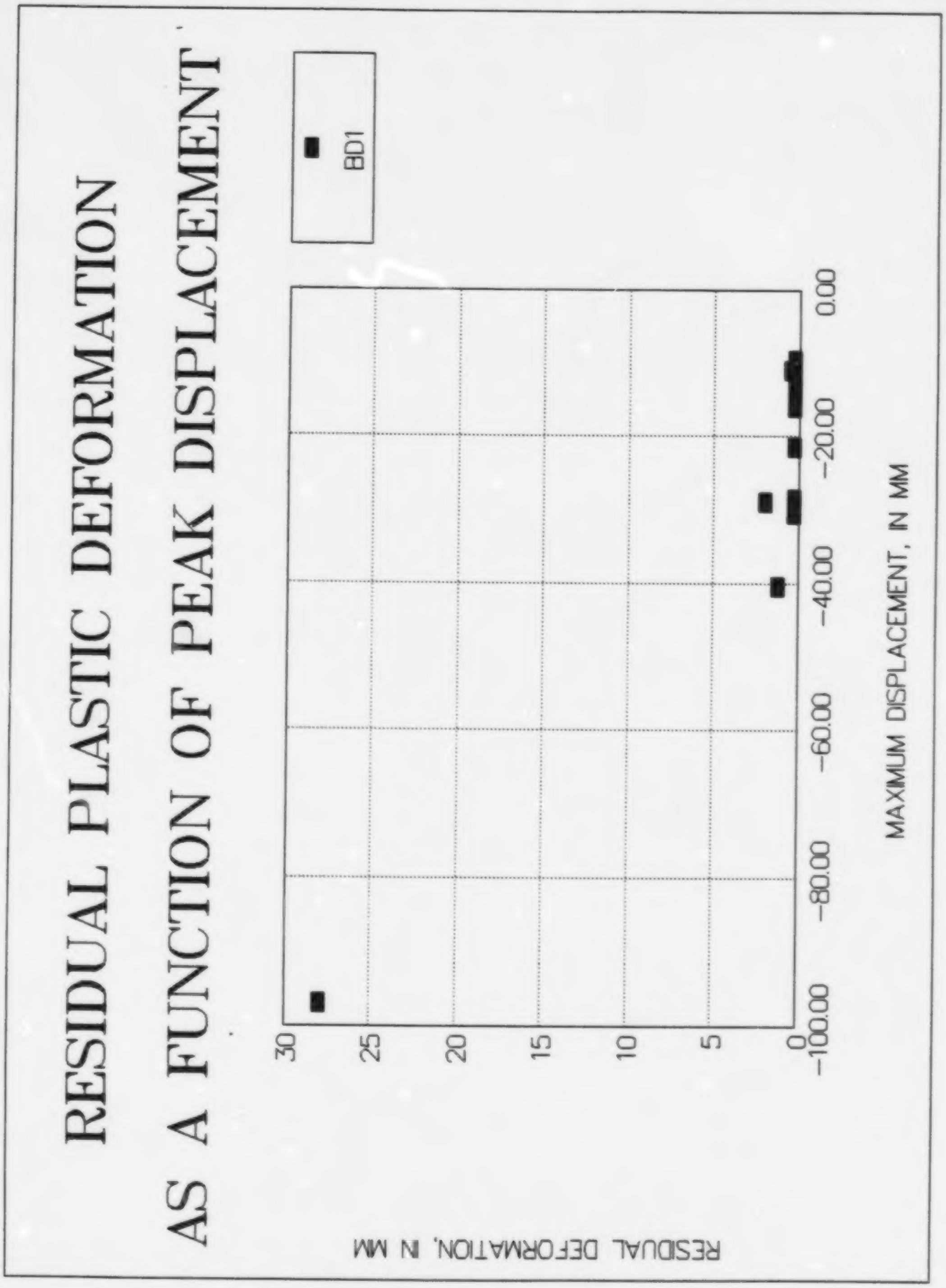

RESIDUAL PLASTIC DEFORMATION AS A FUNCTION OF PEAK DISPLACEMENT

FIGURE 5.4.13

RESIDUAL PLASTIC DEFORMATION AS A FUNCTION OF PEAK DISPLACEMENT

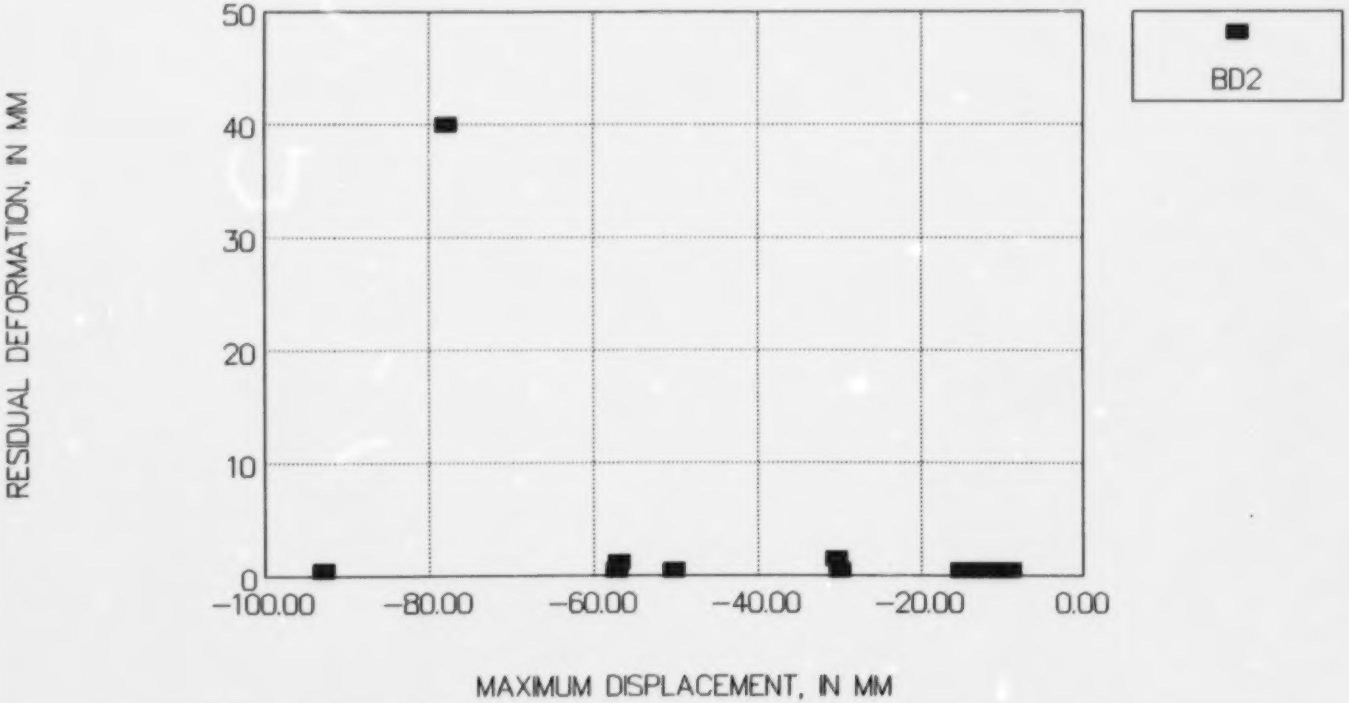
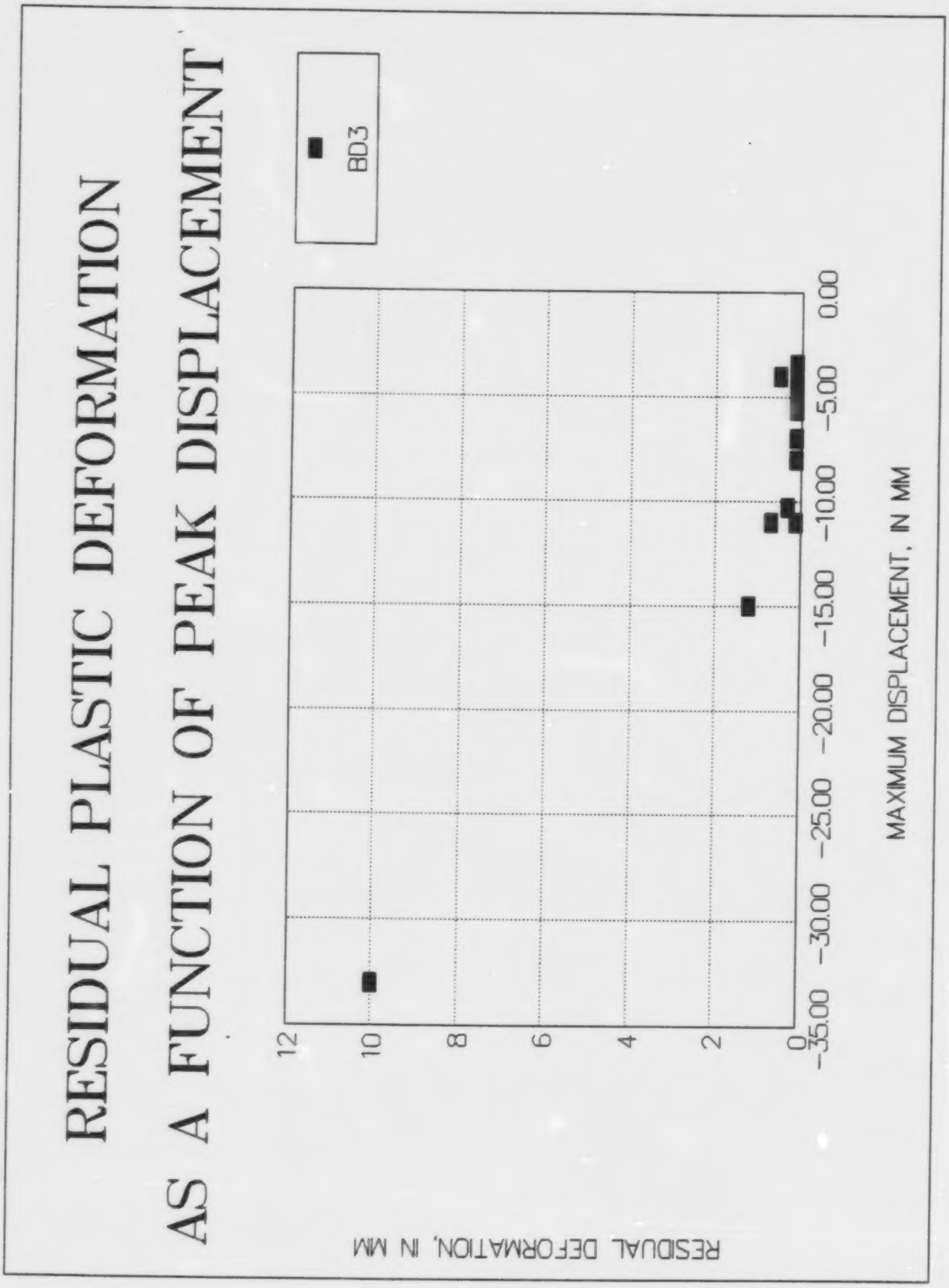


FIGURE 5.4.14



RESIDUAL PLASTIC DEFORMATION AS A FUNCTION OF PEAK DISPLACEMENT

FIGURE 5.4.15

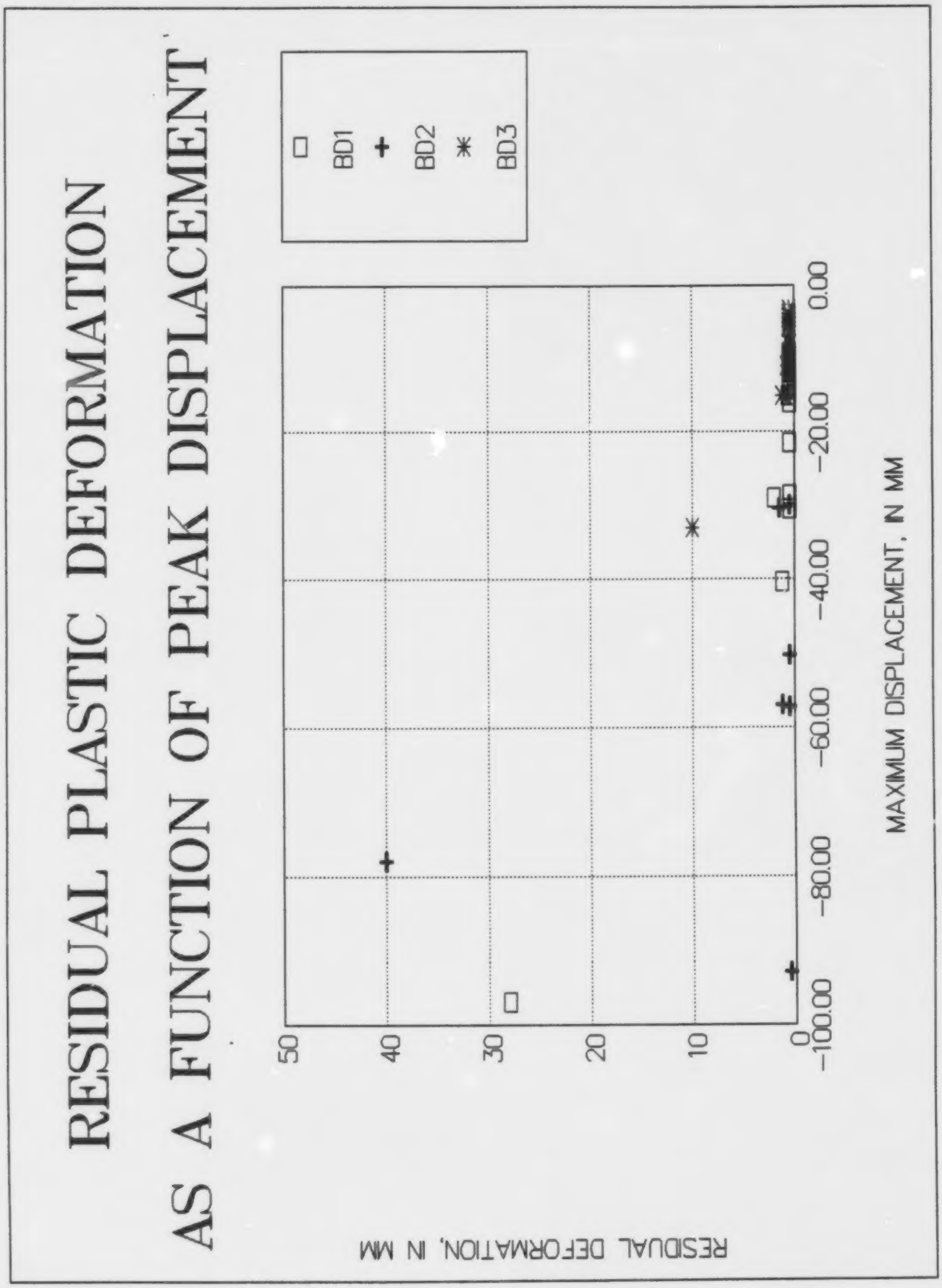

RESIDUAL PLASTIC DEFORMATION AS A FUNCTION OF PEAK DISPLACEMENT

TABLE 5.4.5

SUMMARY OF STRAINS AND STRESSES

TEST	MAX	MAX BLADE STRAINS					PRINCIPAL STRESSES AT THE PEAK								PRINCIPAL STRESSES	
NR	LOAD	BR1A		BR1B		BR1C	MEGAPASCALS		BR2A		BR2B		BR2C		MEGAPASCALS	
	MN	MICROSTRAINS					SIGMA1	SIGMA2							SIGMA1	SIGMA2
1	0.66			(510)			51	(51)			820				82	(82)
2	0.53	(520)		(710)		(185)	(26)	(105)			840				84	(84)
3	0.53	(560)		(770)		(210)	(29)	(114)			900				90	(90)
4	1.03	(600)		(1,200)		(500)	(37)	(167)			350				35	(35)
5	0.37	(330)		(450)		(130)	(19)	(67)			240				24	(24)
6	0.57	(250)		(360)		(220)	(31)	(56)			720				72	(72)
7	0.37	(390)		(460)		(90)	(18)	(71)			600				60	(60)
8	0.53	(600)		(740)		(120)	(22)	(112)	630		903		194		130	23
9	1.28	(1,260)		(1,400)		(400)	(83)	(226)	420		1,700	100	1,360		259	72
10	0.42	(645)		(560)		30	(15)	(99)								
11	1.13	(1,240)		(1,440)		(230)	(50)	(223)	300		1,800		0		194	(138)
12	1.27	(1,350)		(1,630)		(350)	(65)	(251)	350		1,970		1,450		287	47
14	1.75	(1,700)	80	(2,300)	80	(570)	(81)	(340)	625		2,800		1,950		404	74
15	3.95	(4,800)	3300	(4,000)	4300	(2,750)	(596)	(806)	2,780	1600	4,800	4800	4,600	4300	829	542
18	2.05	(3,100)		(4,300)		(1,100)	(148)	(632)	318		5,150		5,850		918	228
19	2.40	(4,700)	1500	(10,000)	1400	(2,050)	49	(1,302)	320	0	7,700	2400	5,500	1600	1,085	(4)
MAX	3.95	-250	3300	-360	4300	30	51	-51	2780	1600	7700	4800	5850	4300	1084.97	541.75
MIN	0.37	-4800	80	-10000	80	-2750	-596.1	-1302.4	300	0	240	100	0	1600	24.00	-137.82
AVGE	1.18	-1470	1626.7	-1926.9	1927	-591.67	-70.01	-288.88	717.88	800	2086.2	2433	2613	2950	303.54	26.37

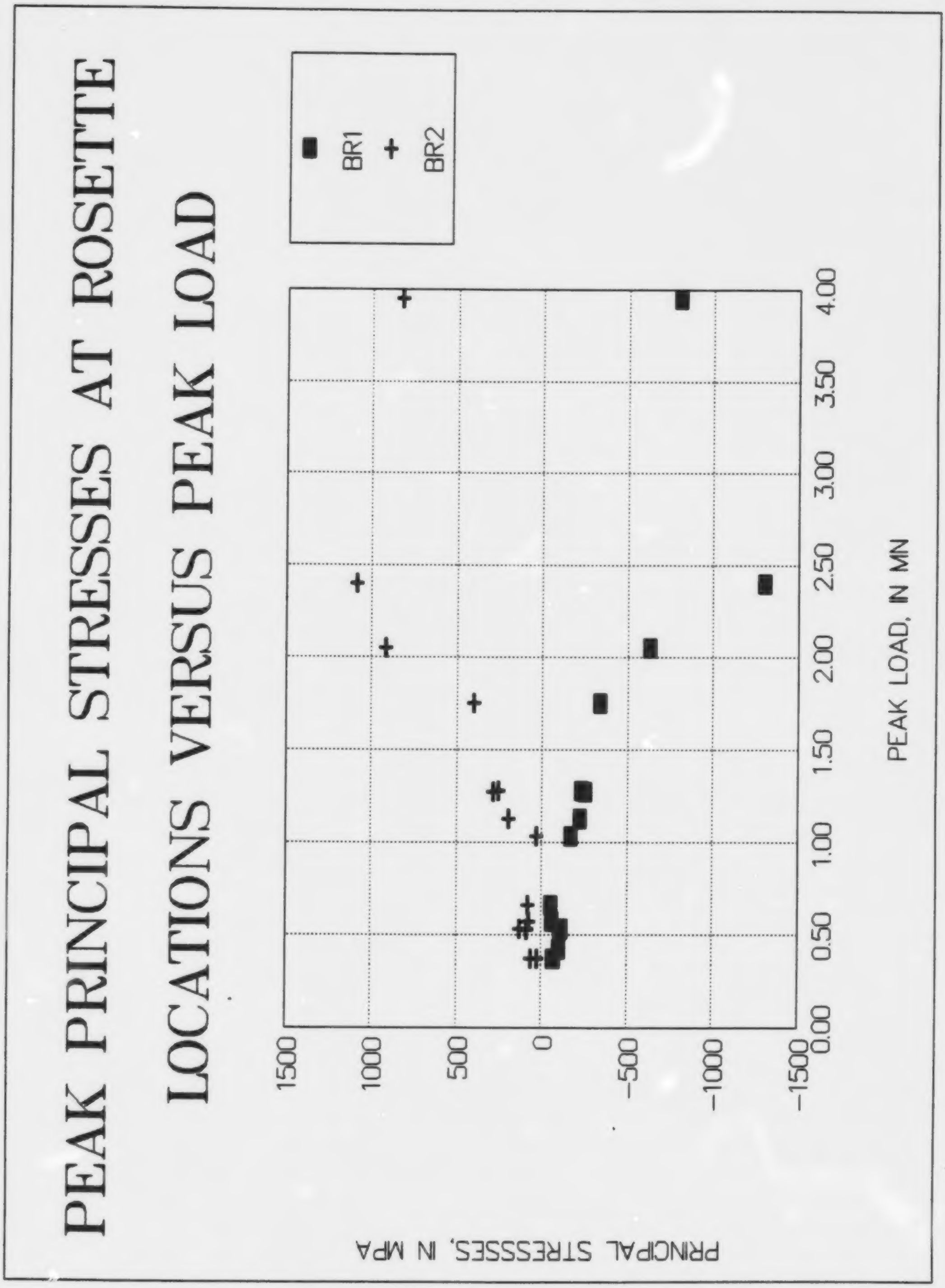
NOTE: STRESSES ABOVE 250 MPA WERE CALCULATED USING LINEAR STRESS/STRAIN RELATIONSHIP, HENCE THEY ARE EXAGGERATED

TABLE 5.4.6

UNIAXIAL STRESSES IN THE ELASTIC AND POST ELASTIC DOMAINS

	STRESSES, IN MPA									
TESTS	BS1	BS2	BS3	BS4	BS5	BS6	BS7	BS8	MINIMUM	BS9
1	-42		-69	-41	-69	-47	-25	-37	-69	94
2	-49		-90	-86	-78	-86	-57	-68	-90	85
3	-65		-100	-90	-83	-92	-59	-73	-100	77
4	-66		-140	-33	-125	-36	-23	-29	-140	30
5	15	-25	-47	-57	-47	-59	-34	-19	-59	16
6	-9		-62	-25	-62	-34	-18	-27	-62	26
7	-27		-68	-77	-53	-65	-52	-52	-68	57
8	-47	-109	-92	-120			-87	-86	-120	88
9	-105	-102	-143	-203			-202	-195	-203	196
10	-5	-107	-46				-129	-102	-129	96
11	-76	-196	-164	-208			-202	-198	-208	200
12	-92	-107	-182	-206			-200	-198	-206	200
14	-61	-91	-202	-206			-200	-207	-206	206
15	-59	-57	-222	-231			-233	-245	-233	242
18	-219	-233	-273	-290			-272	-237	-290	254
19	-253	-237	-290	-290			-273	-259	-290	290
MAX	15	-25	-46	-25	-47	-34	-18	-19	-59	290
MIN	-253	-237	-290	-290	-125	-92	-273	-259	-290	16
AVGE	-73	-126	-137	-144	-74	-60	-129	-127	-155	135

Figure 5.4.16.


PEAK PRINCIPAL STRESSES AT ROSETTE
LOCATIONS VERSUS PEAK LOAD
BR1
BR2
1500
1000
500
0
-500
-1000
-1500
PRINCIPAL STRESSES, IN MPA
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
PEAK LOAD, IN MN

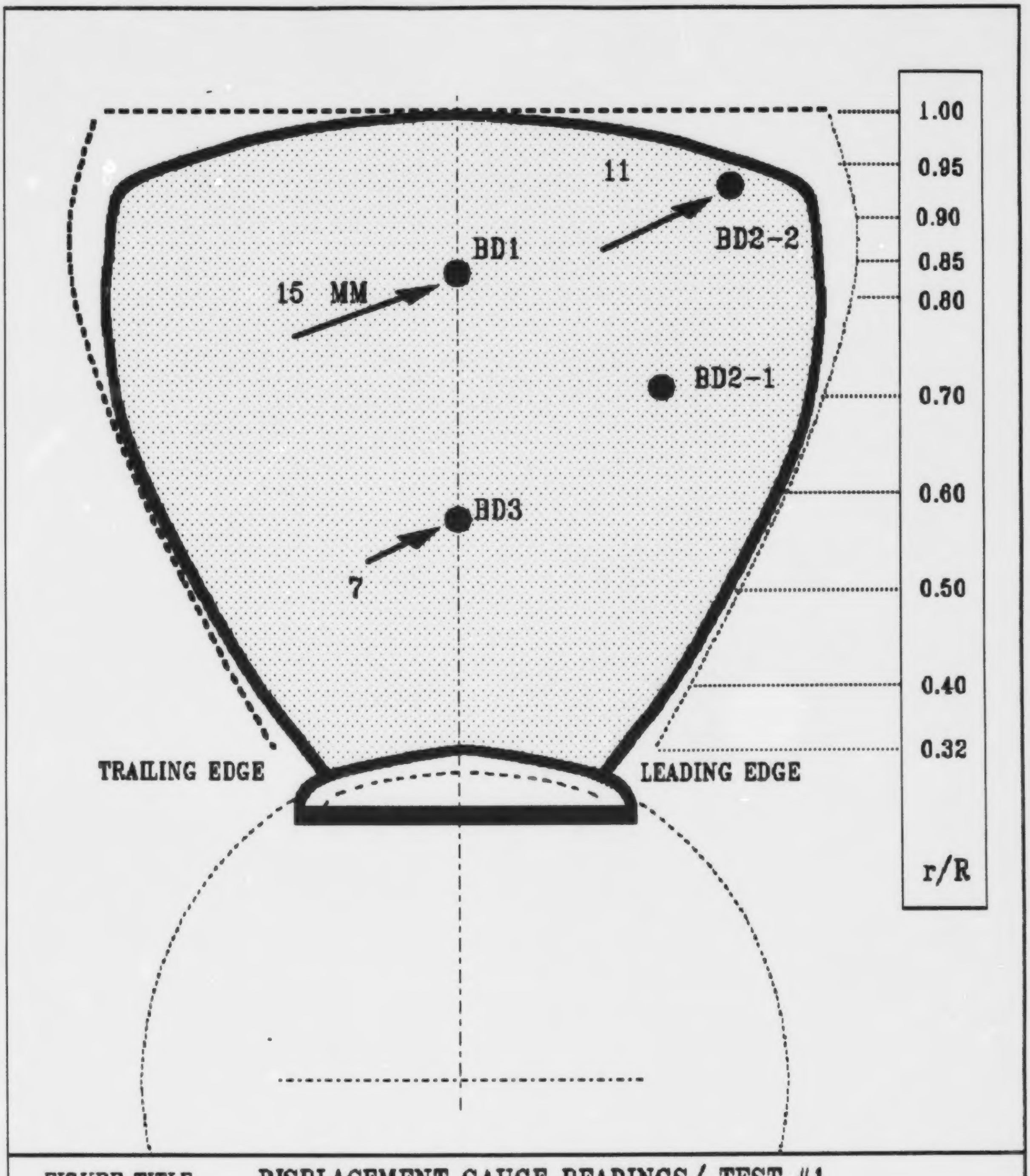

1.00
0.95
0.90
0.85
0.80
0.70
0.60
0.50
0.40
0.32
r/R
11
BD2-2
BD1
15 MM
BD2-1
BD3
7
TRAILING EDGE
LEADING EDGE

FIGURE TITLE: DISPLACEMENT GAUGE READINGS/ TEST #1

PROJECT NAME: FULL SCALE TESTS ON THE BLADE RESPONSE TO ICE

DRAWN BY: JER/VL	**CHK'D BY:** VL	**SCALE:** NONE	**FIGURE NR:** 5.4.17

ARAD

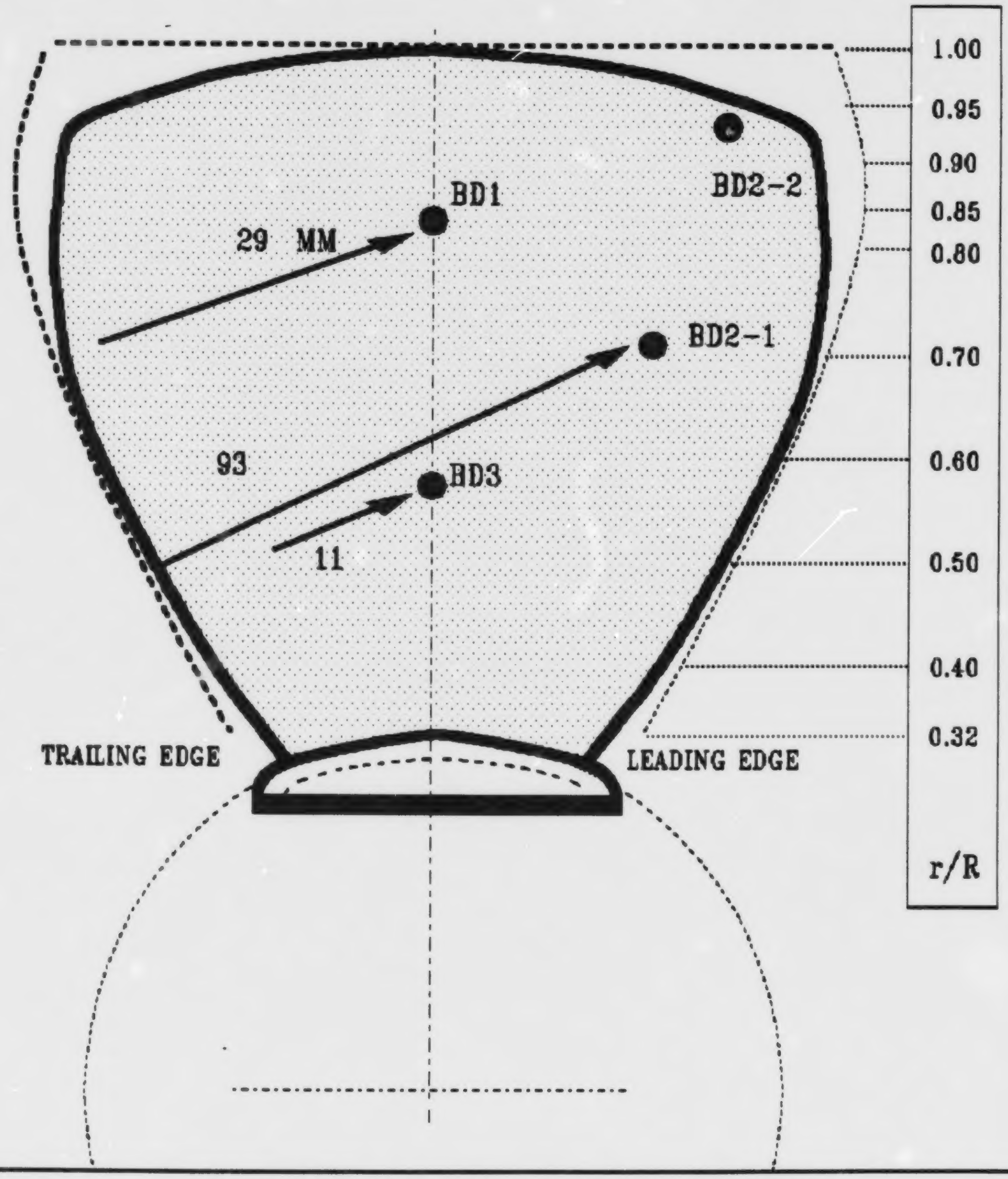

1.00
0.95
0.90
0.85
0.80
0.70
0.60
0.50
0.40
0.32
r/R
BD1
BD2-2
29 MM
BD2-1
93
BD3
11
TRAILING EDGE
LEADING EDGE

FIGURE TITLE: DISPLACEMENT GAUGE READINGS/ TEST #9			
PROJECT NAME: FULL SCALE TESTS ON THE BLADE RESPONSE TO ICE			
DRAWN BY:JER/VL	CHK'D BY: VL	SCALE: NONE	FIGURE NR: 5.4.18

ARAD

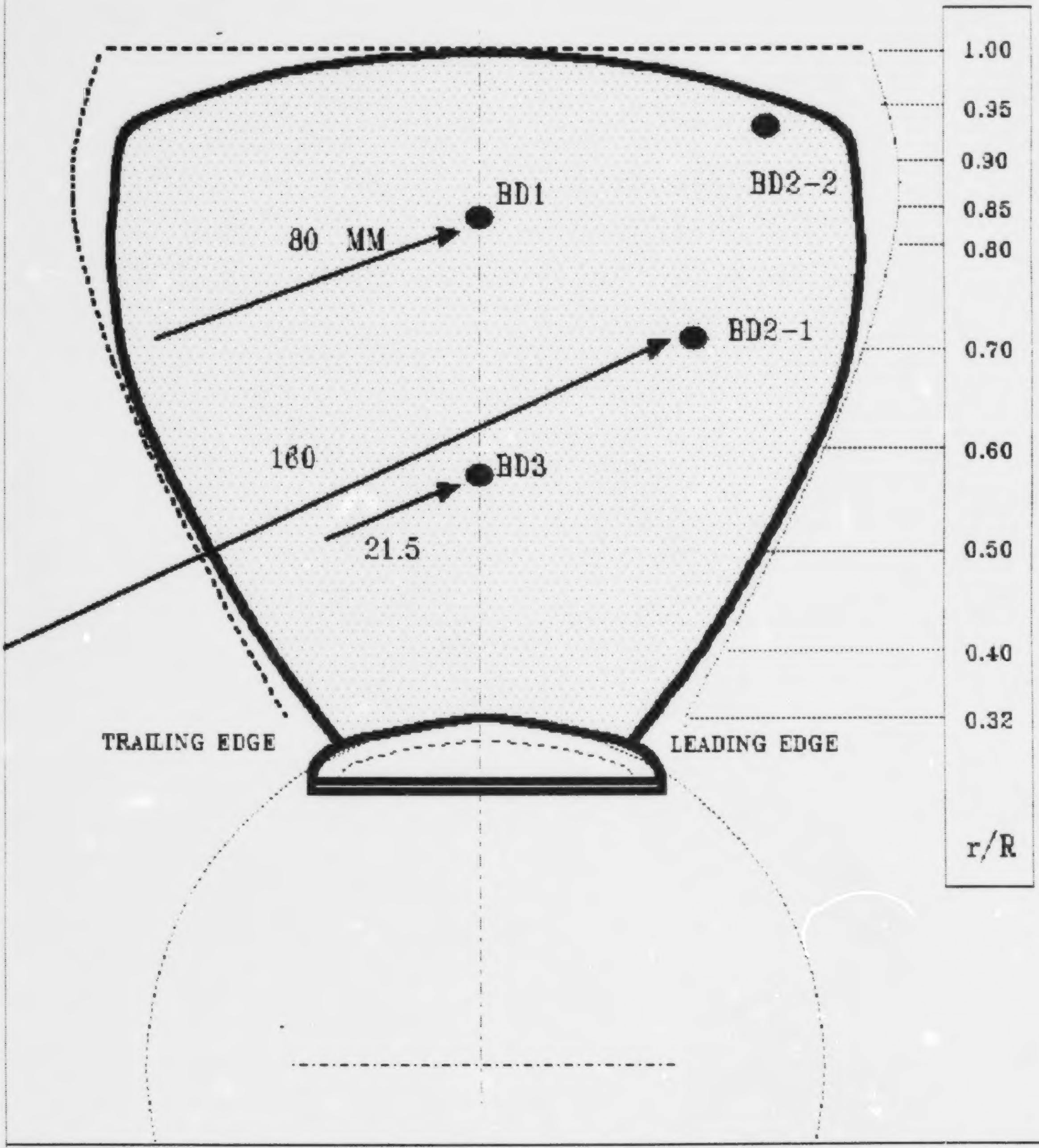

BD1
BD2-2
BD2-1
BD3
80 MM
160
21.5
TRAILING EDGE
LEADING EDGE
1.00
0.95
0.90
0.85
0.80
0.70
0.60
0.50
0.40
0.32
r/R

FIGURE TITLE:	DISPLACEMENT GAUGE READINGS/ TEST #18		
PROJECT NAME:	FULL SCALE TESTS ON THE BLADE RESPONSE TO ICE		
DRAWN BY:JER/VL	CHE'D BY: VL	SCALE: NONE	FIGURE NR: 5.4.19

ARAD

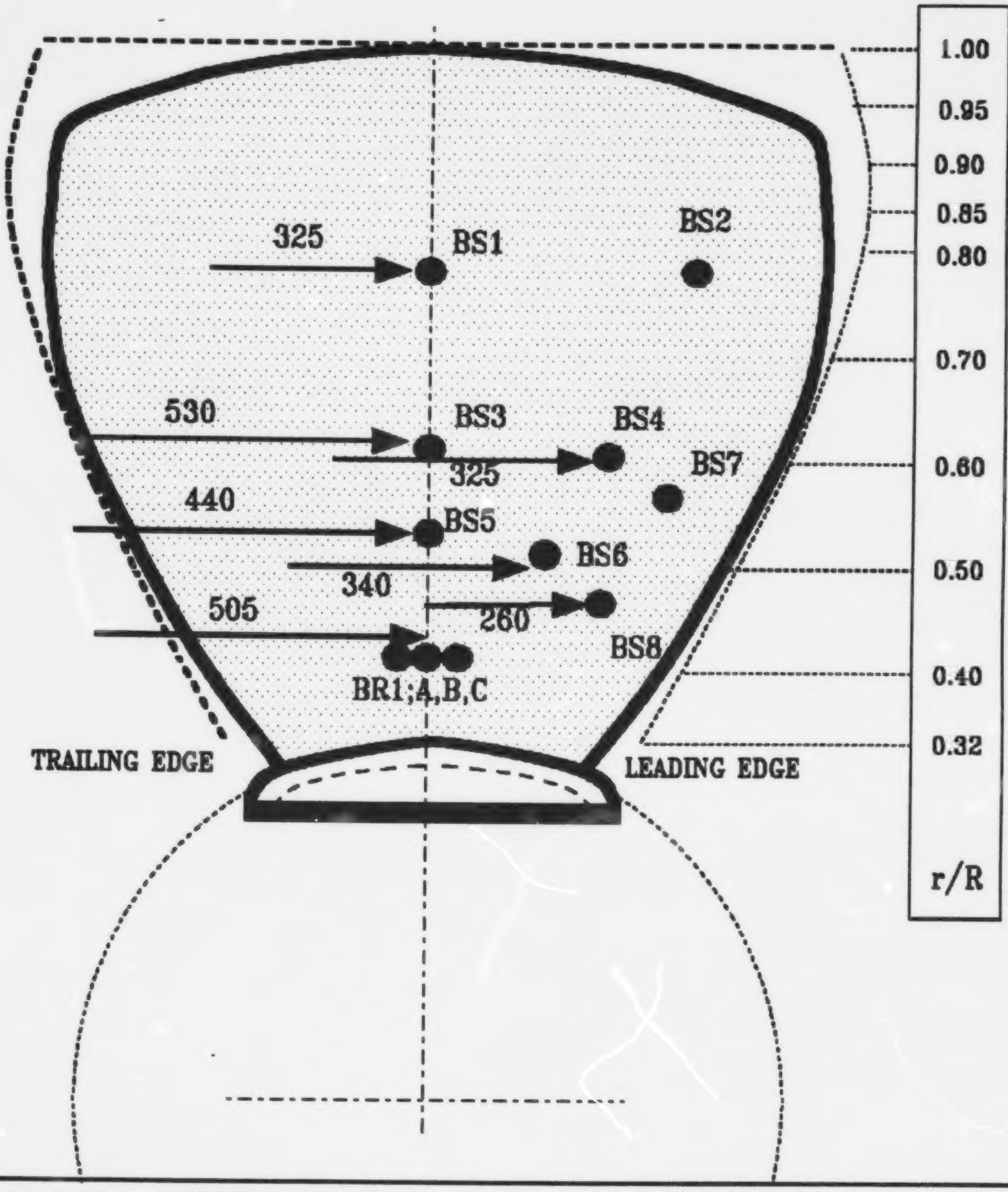

1.00
0.95
0.90
0.85
0.80
0.70
0.60
0.50
0.40
0.32
r/R
325
BS1
BS2
530
BS3
BS4
325
BS7
440
BS5
BS6
340
505
260
BS8
BR1;A,B,C
TRAILING EDGE
LEADING EDGE

FIGURE TITLE: STRAINS AT STRAIN GAUGE LOCATIONS/TEST#1			
PROJECT NAME: FULL SCALE TESTS ON THE BLADE RESPONSE TO ICE			
DRAWN BY:JER/VL	CHK'D BY: VL	SCALE: NONE	FIGURE NR: 5.4.20

ARAD

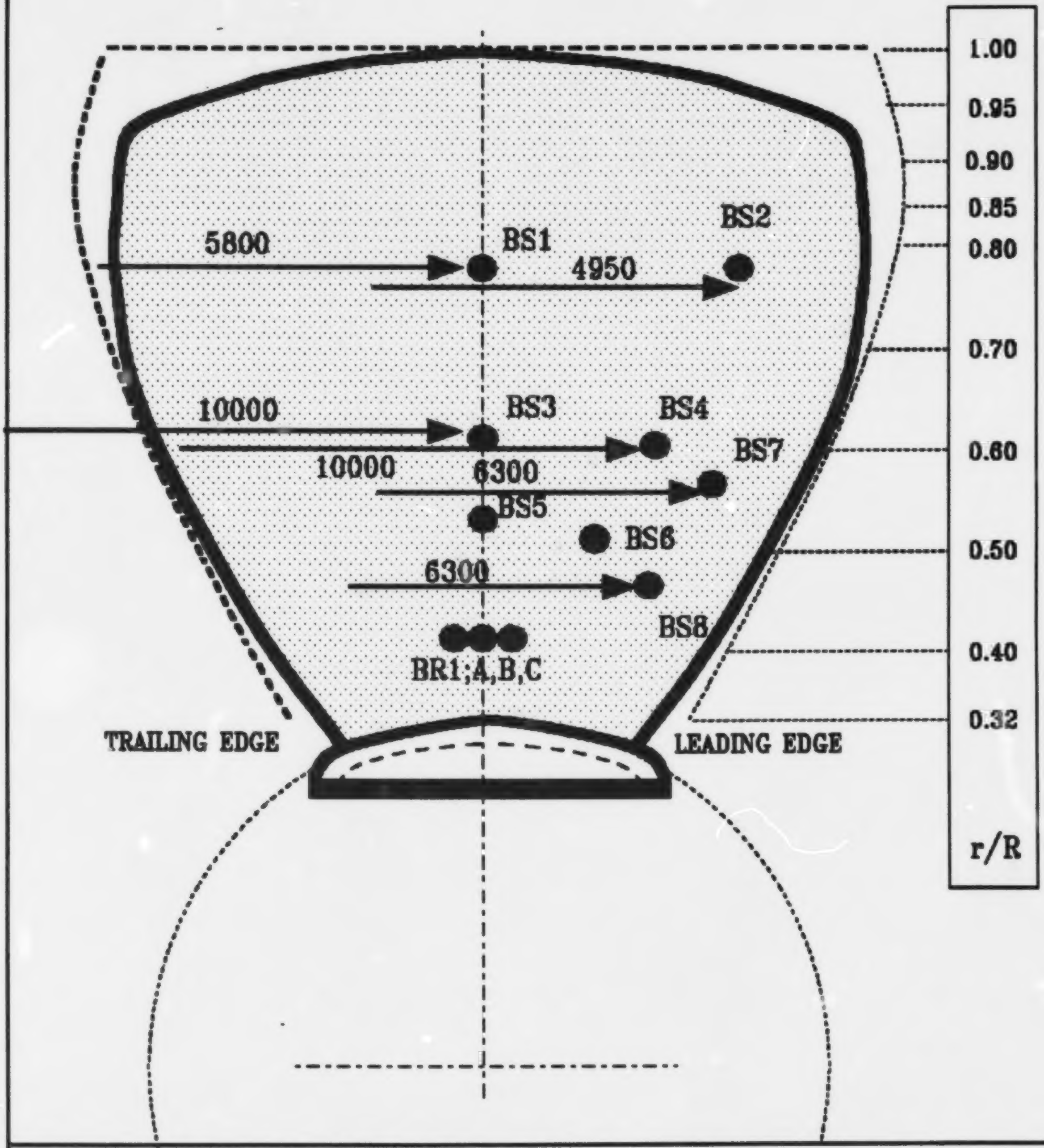

5800
BS1
4950
BS2
10000
BS3
BS4
10000
6300
BS7
BS5
BS6
6300
BS8
BR1;A,B,C
TRAILING EDGE
LEADING EDGE
1.00
0.95
0.90
0.85
0.80
0.70
0.60
0.50
0.40
0.32
r/R

FIGURE TITLE: STRAINS AT STRAIN GAUGE LOCATIONS/TEST#19

PROJECT NAME: FULL SCALE TESTS ON THE BLADE RESPONSE TO ICE

DRAWN BY: JER/VL	**CHK'D BY:** VL	**SCALE:** NONE	**FIGURE NR:** 5.4.21

ARAD

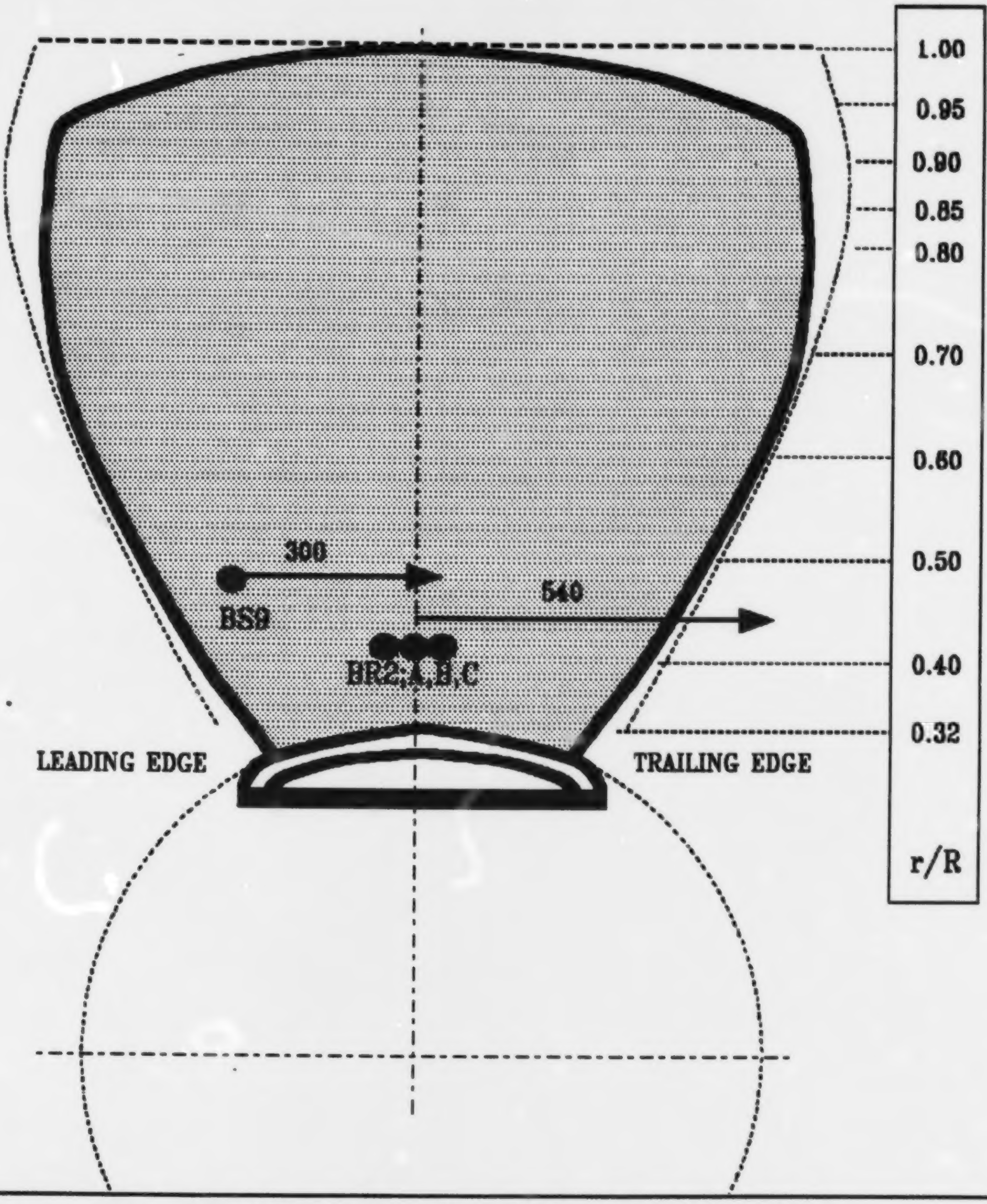

1.00
0.95
0.90
0.85
0.80
0.70
0.60
0.50
0.40
0.32
r/R
300
BS9
540
BR2;A,B,C
LEADING EDGE
TRAILING EDGE

FIGURE TITLE: STRAINS AT STRAIN GAUGE LOCATIONS TEST#1			
PROJECT NAME: FULL SCALE TESTS ON THE BLADE RESPONSE TO ICE LOADS			
DRAWN BY: VL	CHK'D BY: VL	SCALE: NONE	FIGURE NR: 5.4.22

ARAD

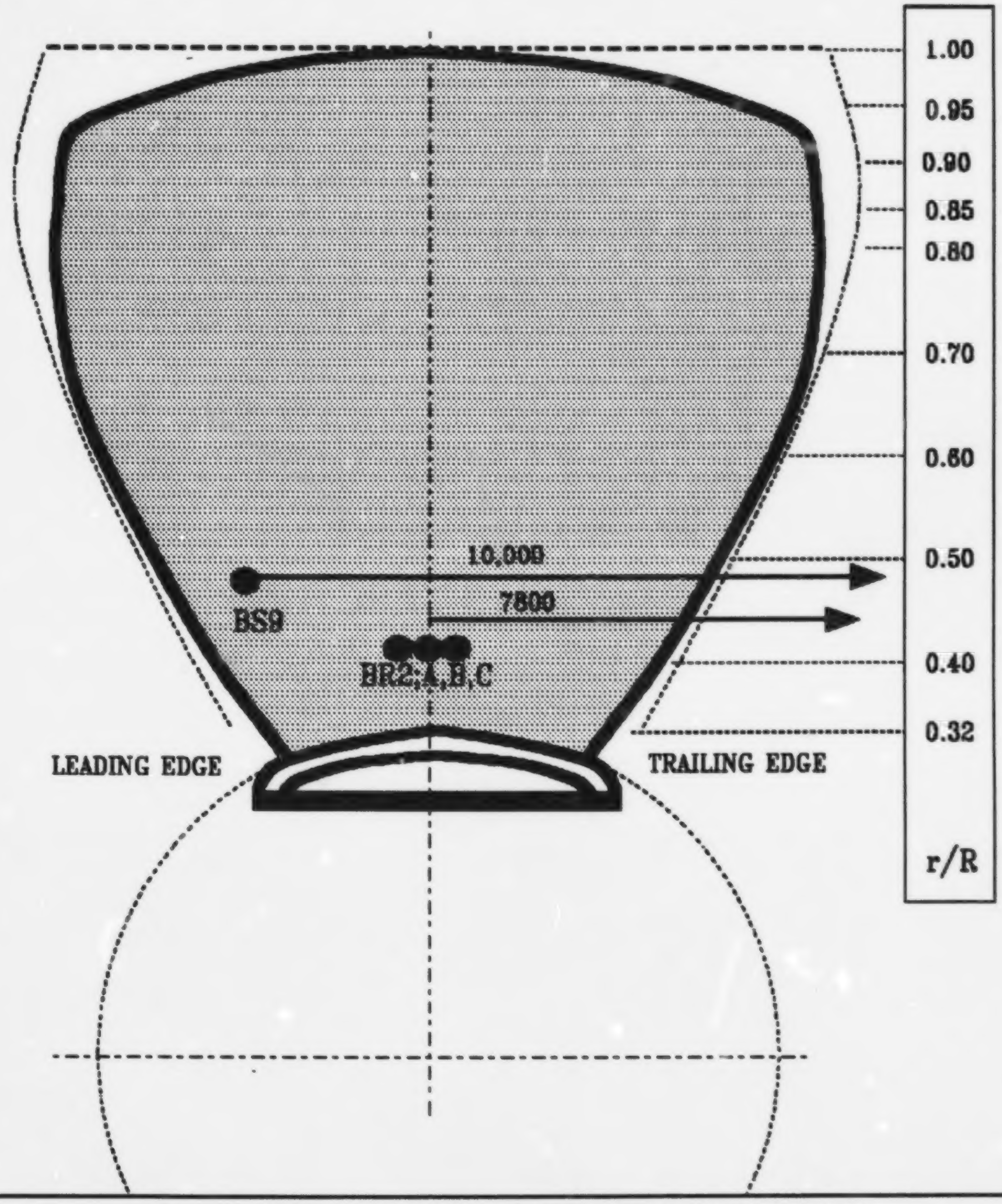
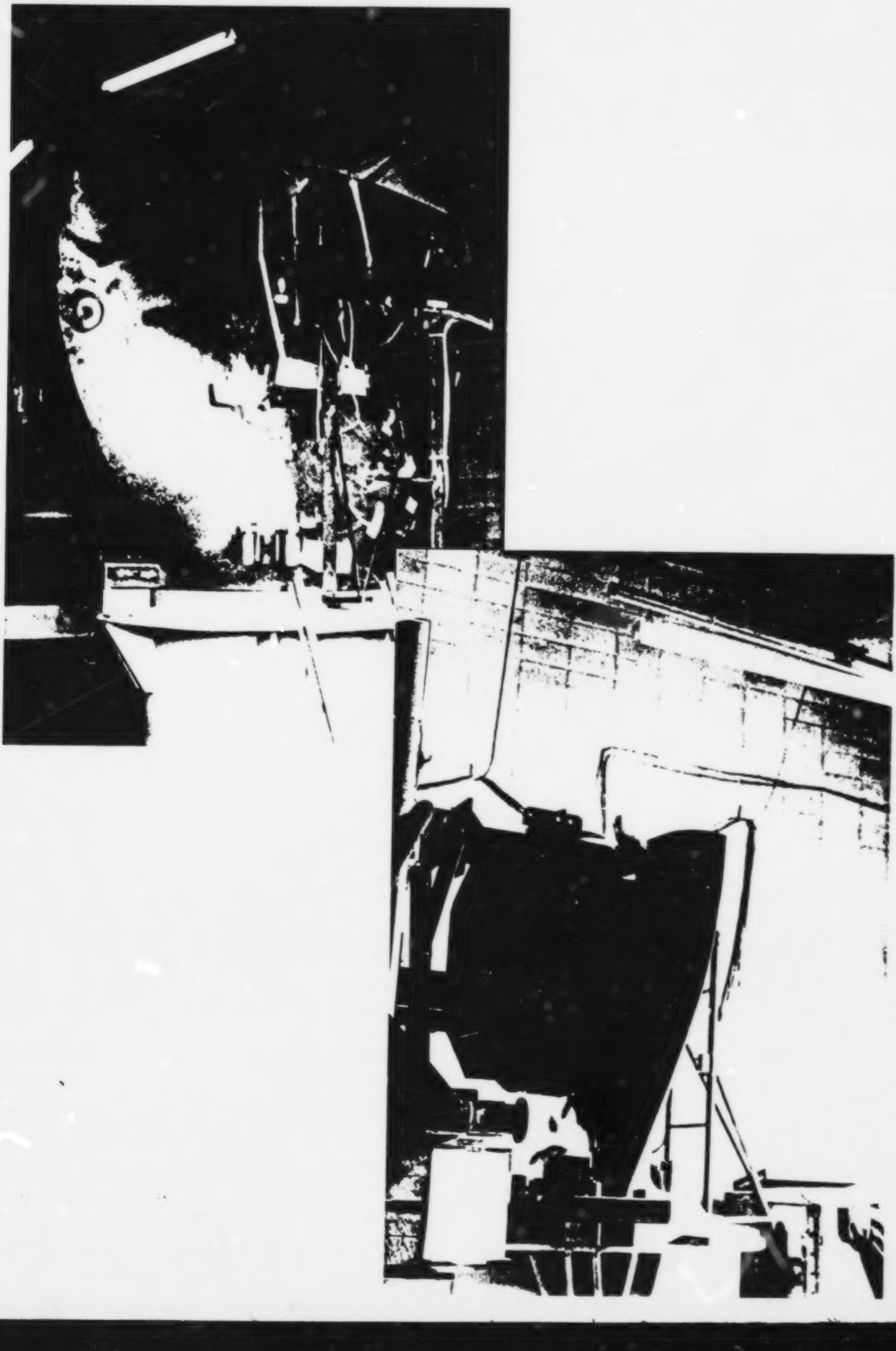

1.00
0.95
0.90
0.85
0.80
0.70
0.60
0.50
0.40
0.32
r/R
10,000
7800
BS9
BR2;A,B,C
LEADING EDGE
TRAILING EDGE

FIGURE TITLE: STRAINS AT STRAIN GAUGE LOCATIONS TEST#19

PROJECT NAME: FULL SCALE TESTS ON THE BLADE RESPONSE TO ICE LOADS

DRAWN BY: VL | CHK'D BY: VL | SCALE: NONE | FIGURE NR: 5.4.23



5.5 Identify the level of the loads, at which the plastic deformations occur.

Figure 5.5.1 shows the residual plastic deformations as a result of the peak loads recorded during the tests. The following observations are made:

1. *Significant deformations (more than 1mm) occur already at peak loads above 1.25MN, which is more than five times the blade hydrodynamic thrust at the bollard.*

2. *At the location BD2 (near the leading edge) the plastic deformations were the highest.*

3. *The lowest plastic deformations took place at BD3 (25% of the maximum plastic deformation).*

4. *Small deformations (less than 1mm) occur already at load levels of 0.5MN, which is 2.2 times the bollard thrust of the blade.*

Figure 5.5.2 shows the dependence of the maximum blade strains on the maximum loads. The linear relationship is apparent. The scatter is attributed to the fact that not all of the maximum strains occurred at the maximum loads and that the directions of the strain gauges were not necessarily the directions of the principal strains.

The onset of yield strain at the gauge locations is shown in Figures 5.5.3 and 5.5.4 for the rosettes and single axis gauges, respectively. It is clear from these graphs that about 2 MN load large plastic deformation begins. However, the dependence of the residual plastic strain on the magnitude of the peak load is sensitive to the gauge location and it is not linear.

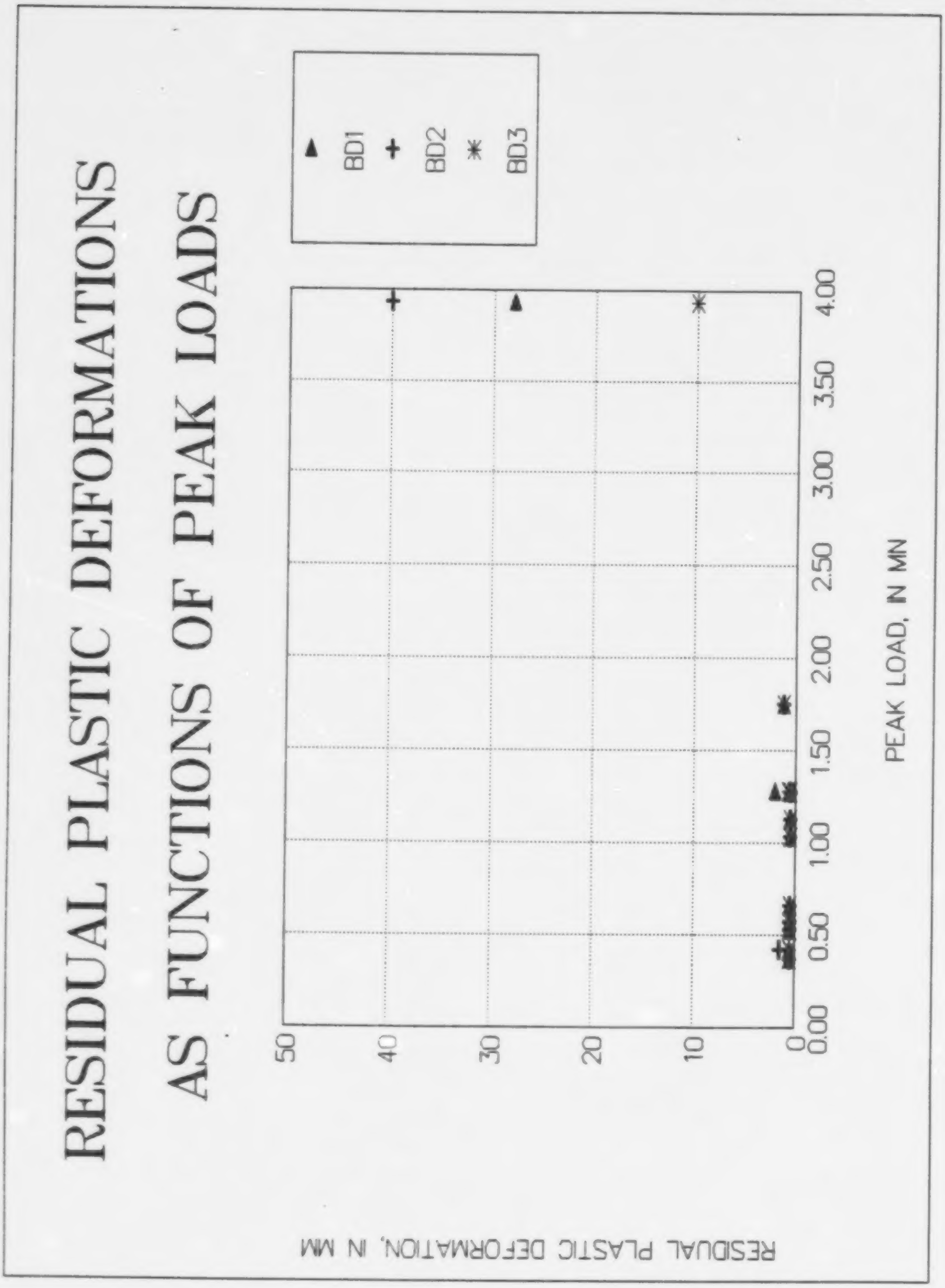
The maximum strains of 10,000 were recorded during the tests.

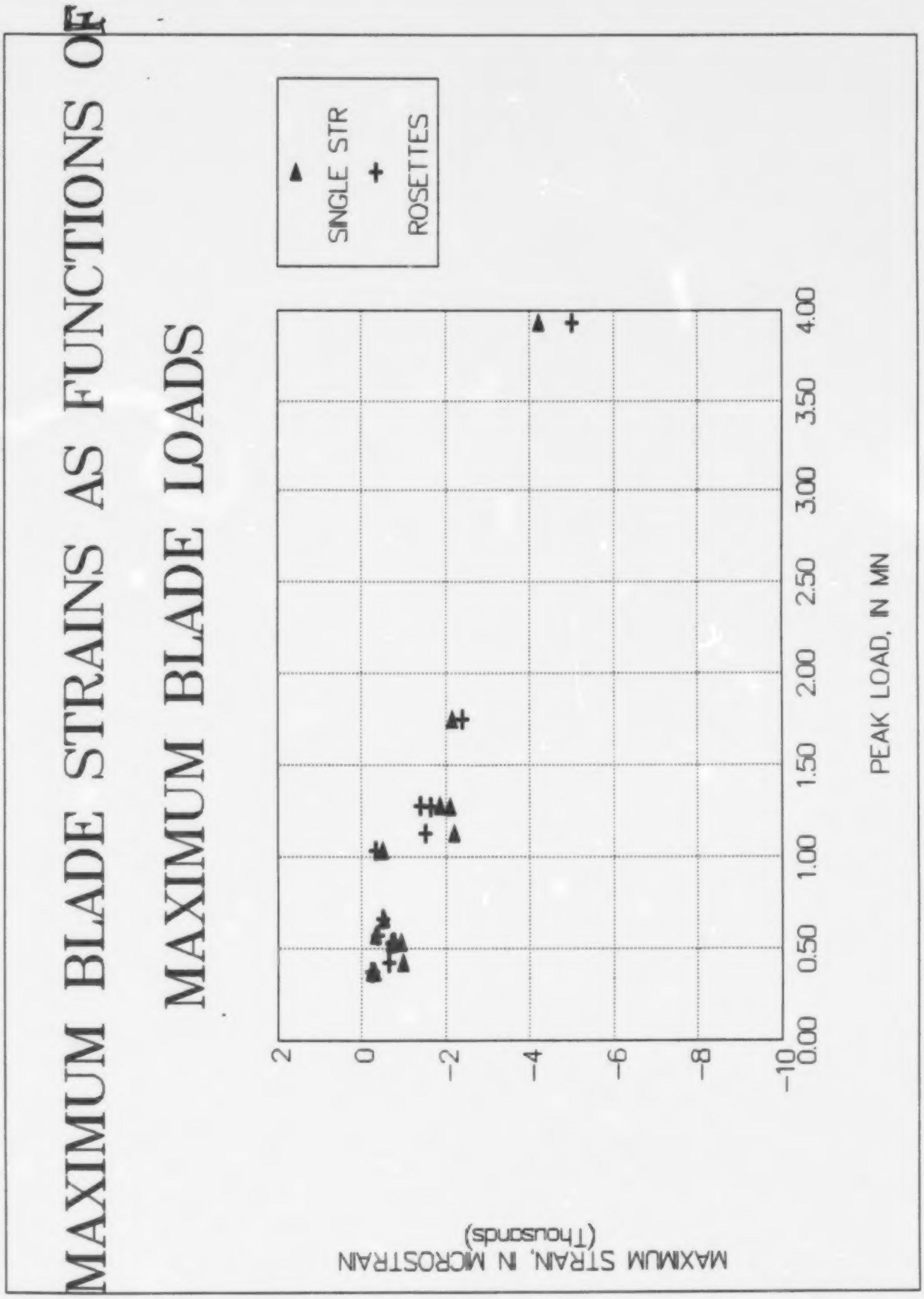
Examining the strain table leads to the conclusion that the calculated yield strain of 2,000 microstrains does not lead to the plastic deformation. The permanent plastic deformation is associated (in most cases) with strains of the order of 5,000.

Conclusions

1. *Small plastic deformations begin at load levels of 0.5 MN.*
2. *Large plastic deformations begin at the load level of 2 MN.*
3. *Largest plastic deformation occurred at the location BD2.*
4. *Large plastic deformation begins at the strain level 5000 microstrains*
5. *Maximum strains of 10,000 microstrains were recorded during the tests, which is 5 times the reference yield strain.*

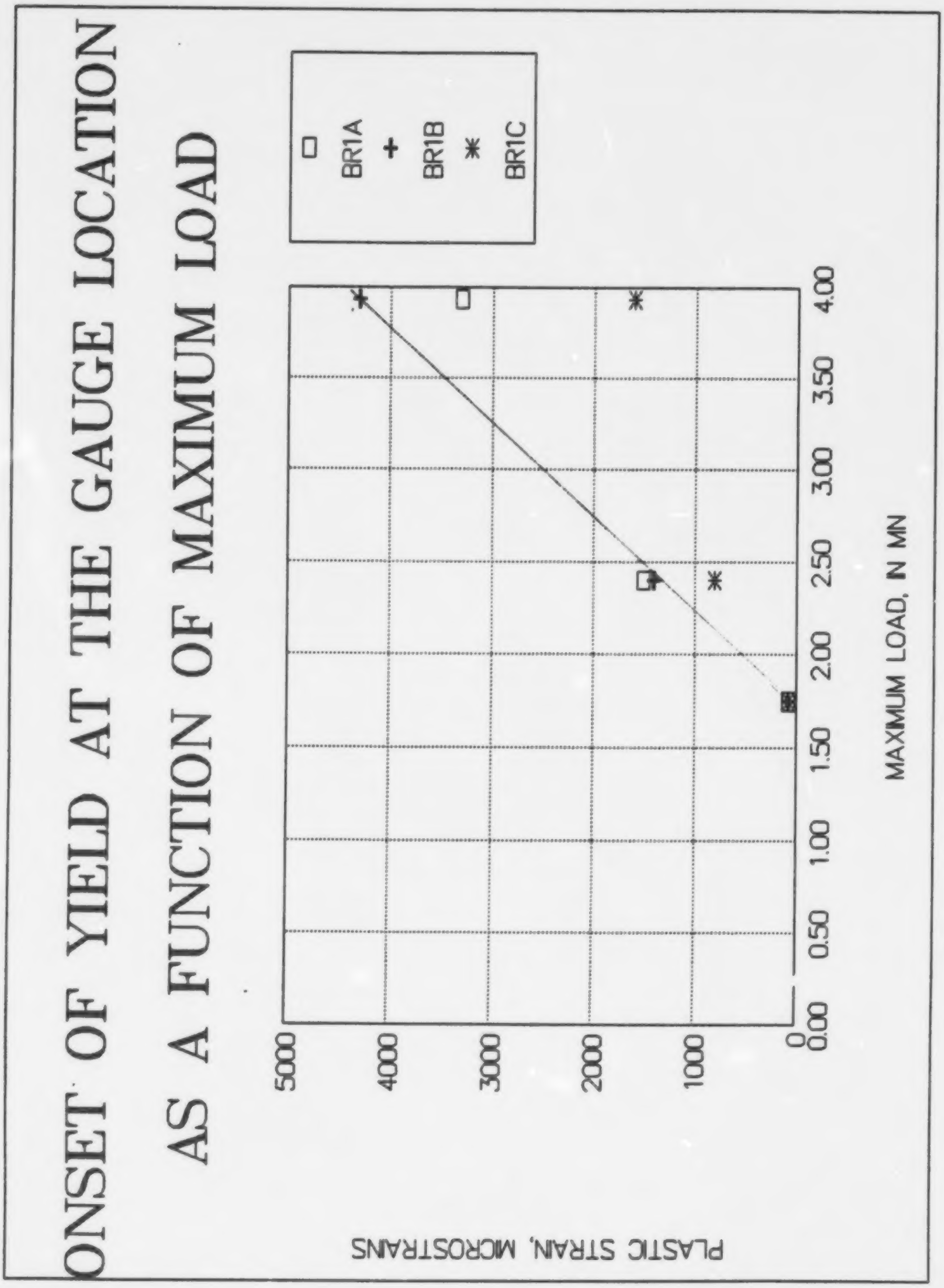
FIGURE 5.5


RESIDUAL PLASTIC DEFORMATIONS
AS FUNCTIONS OF PEAK LOADS
RESIDUAL PLASTIC DEFORMATION, IN MM
PEAK LOAD, IN MN
0
10
20
30
40
50
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
▲ BD1
+ BD2
✳ BD3



MAXIMUM BLADE STRAINS AS FUNCTIONS OF MAXIMUM BLADE LOADS

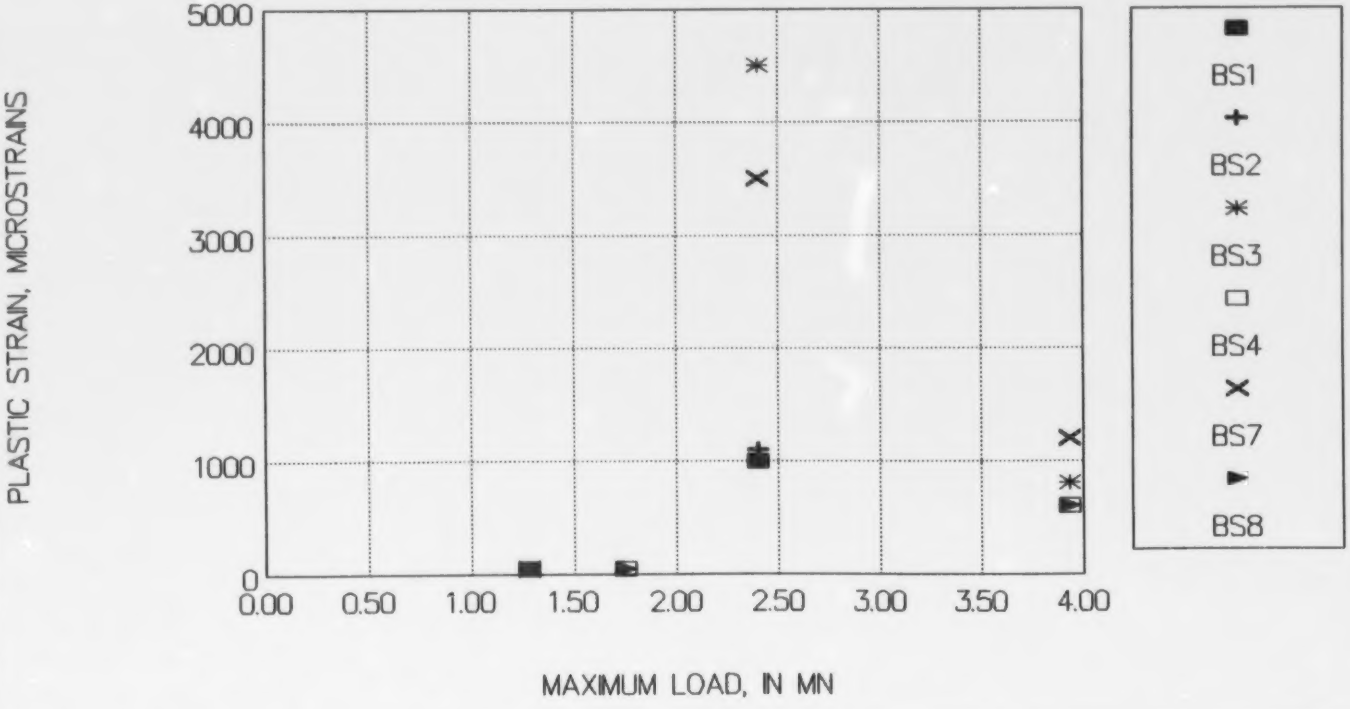
Figure 5.5.3.



ONSET OF YIELD AT THE GAUGE LOCATION AS A FUNCTION OF MAXIMUM LOAD

Figure 5.5.4.

ONSET OF YIELD AT THE GAUGE LOCATION AS A FUNCTION OF MAXIMUM LOAD



5.6. Quantification of the energy aspects of the response, in particular in the post elastic range.

5.6.1. Ice/blade interaction energy - input.

Table 5.6.1 gives details of the energy delivered by the actuators to the interaction, for the first ice failure load and the maximum load as well. The following parameters are calculated from the data:

equivalent momentum developed by the actuators,
work used to reach the peak load,
mean power of the interaction, and
equivalent mass of interaction.

The equivalent momentum developed by the actuators was computed by integrating the force - time history which yielded the equivalent impulse delivered to the interaction.

$$d(m * V) = d\,(\text{Impulse}) = F * dt$$

$$\text{momentum} = F * dt \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 5.6.1.$$

This equivalent impulse is, by definition equal to the change of the momentum. As the velocity of advance was constant, the change of momentum can be interpreted as a change of the equivalent mass (see discussion below).

Work done by the actuators on the ice and blade was computed by multiplying the change of momentum by the velocity of advance.

$$\text{Work} = \text{Momentum} * \text{velocity} \ldots\ldots\ldots\ldots\ldots 5.6.2$$

(Note that this energy is twice the kinetic energy of motion in the case of constant mass and changing velocity)

The mean power of the interaction was computed by dividing the total work performed during the interaction by the time of interaction (until the peak load).

$$\text{Power of interaction} = \text{Total work}/\ \text{total time} \ldots\ldots\ldots\ldots 5.6.3$$

Equivalent mass of interaction was computed by dividing the change of the momentum by the velocity of advance.

$$\text{Equivalent mass} = \text{Momentum} / \text{velocity} \ldots\ldots\ldots\ldots\ldots 5.6.4$$

The interpretation of the equivalent mass is as follows.
If a blade of a propeller was advancing against, say, a broken ice field/ridge rubble or similar ice condition, then the velocity of the advance would be the astern speed of the vessel, assumed constant. The blade would gradually encounter more and more mass of the broken ice which it would be pushing astern. This "bulldozing" action would result in a gradual accumulation of the ice mass in front of the blade, which would be given the

momentum equal to that computed above. That ice mass, being accelerated by the blade to its own speed, would absorb the same amount of energy and develop the same reaction force as that computed during the interaction (assuming the ice blocks would not fail in the process).

The following observations are made after examining the Table:

1. *The maximum work performed by the actuators was*

   0.352 MNm,

   during the test #15.

2. *This maximum was more than four times higher than the average energy content of all of the tests, being*

   0.08 MNm.

3. *Ductile tests at low speed of advance had an order of magnitude higher energy than the tests done at higher speeds.*

4. *The work performed until the first peak of ice failure was an order of magnitude smaller than the total work performed during the tests.*

5. *The average time to reach the maximum load was 4.86 sec., and the minimum was 0.35 sec.*

6. *The average energy delivered before the ice failure was*

   0.0047 MNm

7. *The maximum equivalent ice mass was approximately 12 million tonnes, and the average was over one million tonnes.*

8. *The maximum power developed during the tests was 135 kW.*

9. *The power developed during the ductile tests was an order of magnitude lower than that developed during the high speed tests. Therefore the power may serve as an indicator of the type of ice/blade interaction.*

Figure 5.6.1 shows the dependence of the total impact energy on the initial contact area. Two groups of points are apparent (high energy ductile tests and low energy high speed tests). The correlation between the two variables is not very strong. It is clear that the initial contact area cannot influence th final energy input. This is confirmed in Figure 5.6.2., which shows the correlation between the work needed to fail ice and the work performed from the first peak until the maximum load (second peak). There is no correlation between the two variables.

Figure 5.6.3 shows the work needed to fail ice as a function of contact area. A very strong correlation exists between these two variables. The best linear fit is also shown on the drawing.

As the loads are small, the energy delivered to the blade is low and the most of the energy goes into crushing of ice.

Figure 5.6.4 shows that there is no correlation between the average interaction power and the speed of advance.

5.6.2 Energy aspects of the blade response.

In order to assess the blade strain energy, we will utilize the following relationship:

Strain energy (SE) due to the flexure stored in the volume Vol is:

$$SE = c * E * STRAIN^2 * Vol \qquad \text{5.6.5}$$

where c is a constant,

E is the elastic modulus ($1.3 * 10^{11}$ Pa), and
Vol is the volume of the blade material ($0.35\ m^3$).

That is the energy is proportional to the strain squared.

To reach the yield in uniaxial tension for CUNIAL, the energy is proportional to $(0.002)^2$ =

4/1,000,000 strains squared.

To fail the blade (at 0.2 strains), the energy is proportional to

40,000/1,000,000 strains squared.

which gives a factor of 10,000 between the two energy levels.

Table 5.6.2. gives the summary of the maxima strains squared for the rosettes and the uniaxial strain gauges for all of the tests. The values are proportional to the strain energy stored by the blade.

The following observations are made:

1. The maximum strain squared was 100/1,000,000 (100 million microstrains^2)

   This level of strain energy was reached during the "timber tests", ie tests 18 and 19.

2. *This level is 25 times larger than the amount needed to reach the yield of the blade material in uniaxial tension, but only 1/400 of the energy needed to reach UTS of the blade material.*

3. *All high speed tests showed the amount of strains squared at least two order of magnitude lower than the timber tests, for the uniaxial gauges.*

As an example of the strain energy computation we take run #14 (ductile) where permanent deformation was noted on the blade displacement gauges.

The total load acting on the blade was computed as follows (see Figure 5.6.5 for the reference):

$$\text{total load (MN)} = 0.0153 * t^{1.6}$$

where t is the time from the beginning of interaction (at 59sec into the test). After 20 seconds the load reached the peak of 1.85 MN.

The blade displacement at BD2 was calculated using the following expression:

$$\text{displacement} = 0.0028 * t$$

Integrating these two expressions to obtain the energy input into the blade we get:

$$\text{work} = \text{strain energy} = 1.65 * 10^{-5} * t^{2.6}$$

At the peak load (t = 20 sec), the strain energy input becomes:

$$SE = 0.04 \text{ MNm}$$

When this number is compared with the total work done by the actuators of 0.056 MNm (see Table 5.6.1), we reach the conclusion that

***71%** of the work went into the blade and*
***29%** went into the ice.*

The blade displacement gauge showed the permanent set of 2mm. If we approximate the plastic deformation loop by a triangular shape, we get the energy of plastic deformation as:

$$\text{Plastic deformation energy} = F\text{max} * \text{set}/2$$

which gives

Plastic deformation energy = 0.00185 MNm, which is

3.3% of the total energy developed and
4.6% of the total strain energy.

Note that the permanent set was 3.8% of the total displacement.

If the point of application of the load was at BD1, having the maximum displacement of 40mm, then by applying exactly the same procedures we will get:

SE = 0.04 *40/56 = 0.029 MNm, which is 64% of the total

work expanded.

The permanent set of 2.2 mm at the BD1 gives the plastic strain energy of 0.002 MNm, which is 7% of the total energy input into the blade.

As the actual load drifted during the interaction somewhere between the location BD12 and BD2, we conclude that the actual numbers lie between the two sets of numbers computed above.

Nevertheless, we conclude that, for this particular test, more than 64% of the total energy went into the blade, and the permanent deformation energy was a small percentage (less than 7%) of the total strain energy.

Test #4 is a good example of the brittle failure of ice followed by the extrusion process.
Figure 5.6.6 shows the displacement versus the total load at the location BD1, nearest to the point of application of the load. The total energy until the peak load was:

1MN * 0.022m/2 = 0.011 MNm

which is

22.4%

of the total work expanded of 0.049 MNm.

Therefore it is clear that in this type of the tests, most of the energy goes into the ice crushing and extraction.
This is confirmed by direct observations of ice extrusion, where ice is being pushed out with high kinetic energy content.

For the test #18 (timber), the work of deformation can be computed from the Figure 5.6.7 as 0.213 MNm, which is

84%

of the total energy delivered.

Test #19 delivers the best example of the large plastic deformation at the gauge location BR2B (tension side), as shown in the Figure 5.6.8.

The area under the hysteresis loop is the work done in plastic deformation. This area is computed to be:

9,000 MN * microstrain

This large area is

75%

of the total area under the strain - load curve of 12,000 MN * microstrains.

That is, 75 % of the strain energy went into the plastic deformation at that location and that test.

Figure 5.6.9 shows the **simplified strain/load relationship** for the test #19 at the selected gauge locations. The following observations are made:

1. At all gauge locations, the initial strain/load curve, which is proportional to the strain/stress curve, is linear. The proportionality constant is dependent on the gauge location, but on the average it is **1,400 microstrains/MN**.
2. At **1MN** load, all curves start deviating from the straight line, which indicates the effect of plasticity.
3. The least linear relationship is exhibited at the location BS7
4. All curves show a pronounced hysteresis loop, the largest being at BS7. The area enclosed by the loop is proportional to the plastic strain energy absorbed by the blade.
5. The areas enclosed by the loops are **more than 50%** of the areas enclosed by the maximum load/ maximum strain curve.
6. The residual strains are within **25 to 42% of** the maximum strain recorded.
7. These curves have the same character as the one discussed above, for the location BR2.

Conclusions:

INPUT ENERGY

1. The maximum input energy was

   0.352 MNm,

   expended during the test #15.

2. The ductile type tests had an order of magnitude higher energy inputs than the brittle type tests.

3. The work needed to fail ice in brittle type tests is an order of magnitude smaller than the total work performed until the peak load was reached.

4. The average energy delivered before the ice failure in brittle tests was

   0.0047 MNm

5. The maximum power developed during the tests was **135 kW.**

6. The ductile tests, performed at a low speed, were of the very low power, order of magnitude lower than the high speed tests.

7. Work needed to fail ice is proportional to the initial contact area.

8. For ductile type of tests, most of the input energy went into the blade **(71%)**

9. For brittle type of tests, most of the input energy goes into the ice crushing and extraction.

BLADE

1. For the large plastic deformation tests (#18 and 19), and location at BR2B (tension side) the plastic deformation energy is

   75%

   of the total energy under the load/strain curve.
   The area under the curve is

   9 Newton * strains

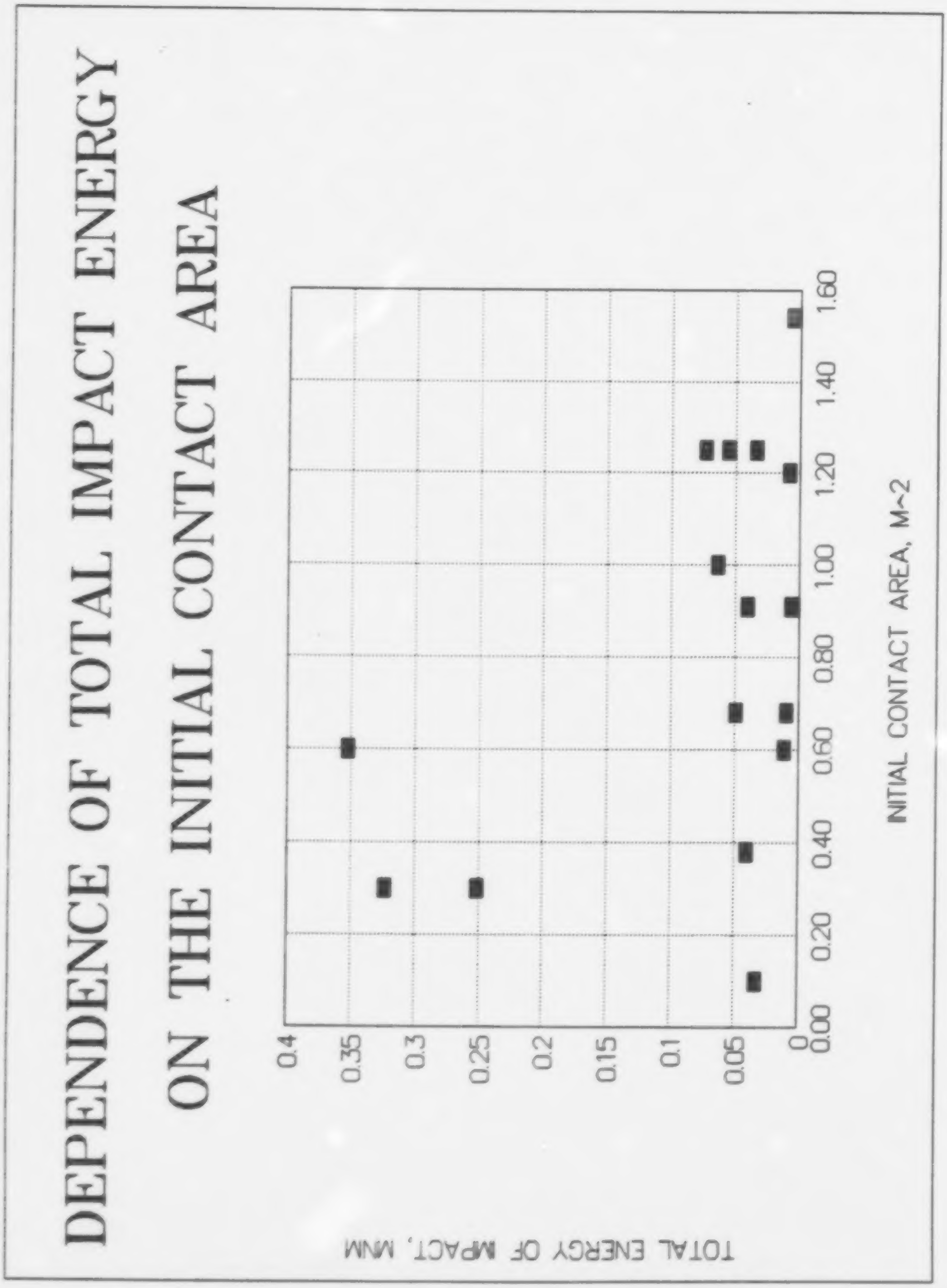
2. Load/strain ratio for the low strains is constant and, on the average, equal to the

1,400 microstrains/MN.

3. At load level of **1 MN,** all load/strain curves start deviating from the linear relationship, for that particular location.
4. For the other gauge locations, a very similar plastic hysteresis loops have been computed, having areas in excess of **50% of the total area (max load*max strain).**
5. For the locations chosen, the residual strains were **25% to 42%** of the maximum strains recorded.

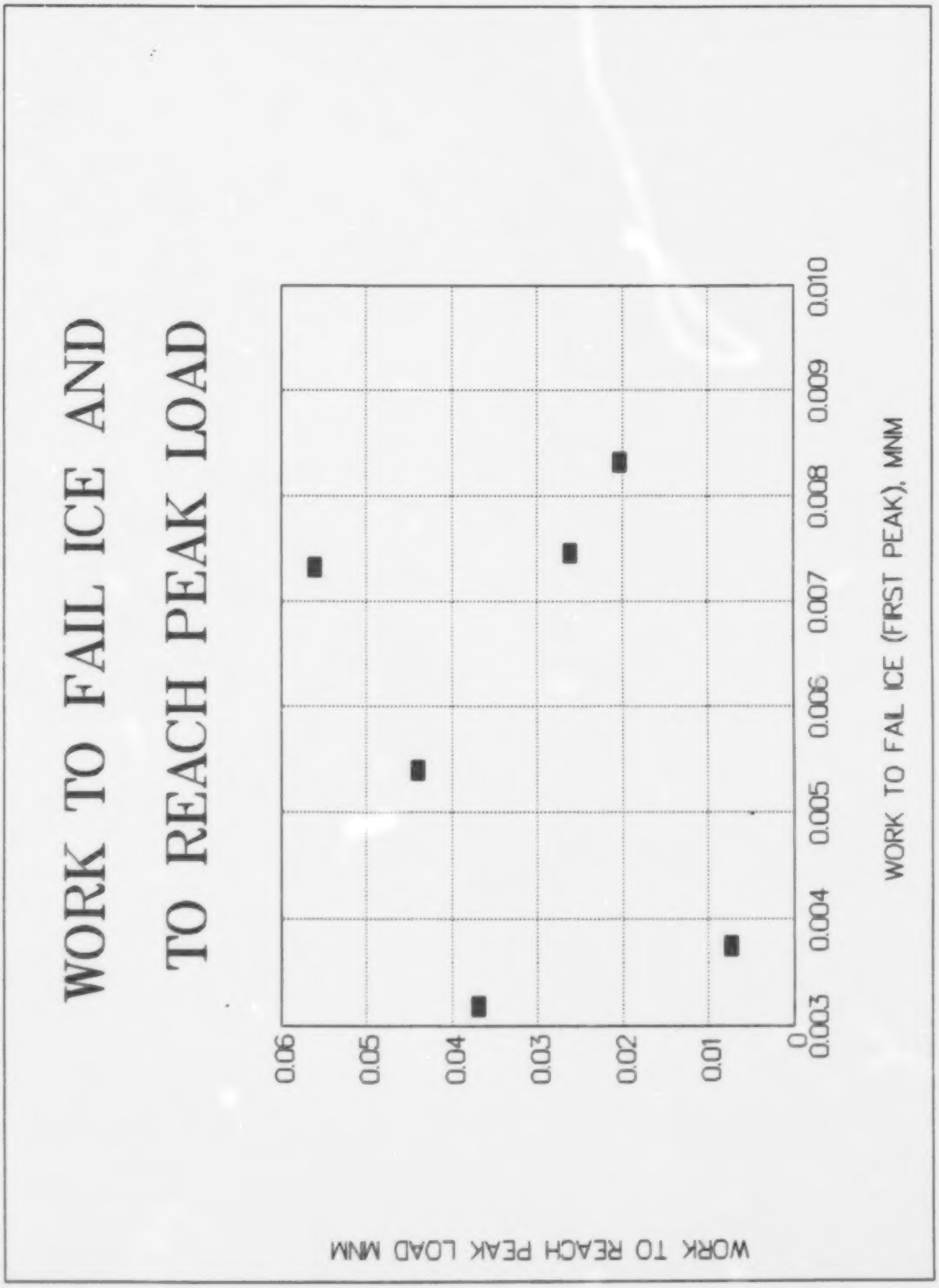
TABLE 5.6.1.
WORK OF INDENTATION/SUMMARY

TEST NR	INITIAL CONTACT AREA M^2	ADVANCE VELOCITY MM/S	MOMENTUM MNSEC FIRST PEAK	MOMENTUM MNSEC SECOND PEAK	WORK MNM FIRST PEAK	WORK MNM SECOND PEAK	WORK MNM TOTAL	MAX TOTAL LOAD MN	EQUIVALENT MASS TONNES 1ST PEAK	EQUIVALENT MASS TONNES 2ND PEAK	MEAN DURATION (TOTAL) SECONDS	MEAN POWER KW (TOTAL)
1	1.00		0.080	0.614	0.007	0.056	0.064	0.66	874	6,710	3.00	21
2	1.54	85.7		0.065		0.006	0.006	0.53		758	0.50	11
3	1.20	83.3		0.094		0.008	0.008	0.53		1,128	0.40	20
4	0.68	100.0	0.054	0.440	0.005	0.044	0.049	1.03	540	4,400	2.10	24
5	0.60	100.0	0.037	0.074	0.004	0.007	0.011	0.37	375	740	1.60	7
6	0.10	101.5	0.024	0.300	0.002	0.030	0.033	0.57	236	2,956	1.00	33
7	0.38	102.7	0.031	0.360	0.003	0.037	0.040	0.37	302	3,505	2.10	19
8	0.68	100.0		0.093		0.009	0.009	0.53		930	0.50	19
9	1.25	100.7	0.074	0.260	0.007	0.026	0.034	1.28	735	2,582	0.75	45
10	0.91	102.9		0.060		0.006	0.006	0.42		583	0.35	18
11	0.91	100.7		0.402		0.040	0.040	1.13		3,992	0.80	51
12	1.25	100.7		0.724		0.073	0.073	1.27		7,190	1.20	61
14	1.25	3.0		18.500		0.056	0.056	1.75		6,166,667	20.00	3
15	0.60	5.5		64.580		0.352	0.352	3.93		11,849,541	39.00	9
18	0.30	103.5		2.430		0.252	0.252	2.05		23,478	2.10	120
19	0.30	102.7		3.150		0.324	0.324	2.40		30,672	2.40	135
MAX	1.54	103.50	0.08	64.58	0.01	0.35	0.35	3.93	874	11,849,541	39.00	135
MIN	0.10	3.00	0.02	0.06	0.00	0.01	0.01	0.37	236	583	0.35	3
AVG	0.81	86.52	0.05	5.76	0.00	0.08	0.08	1.18	510	1,131,615	4.86	37



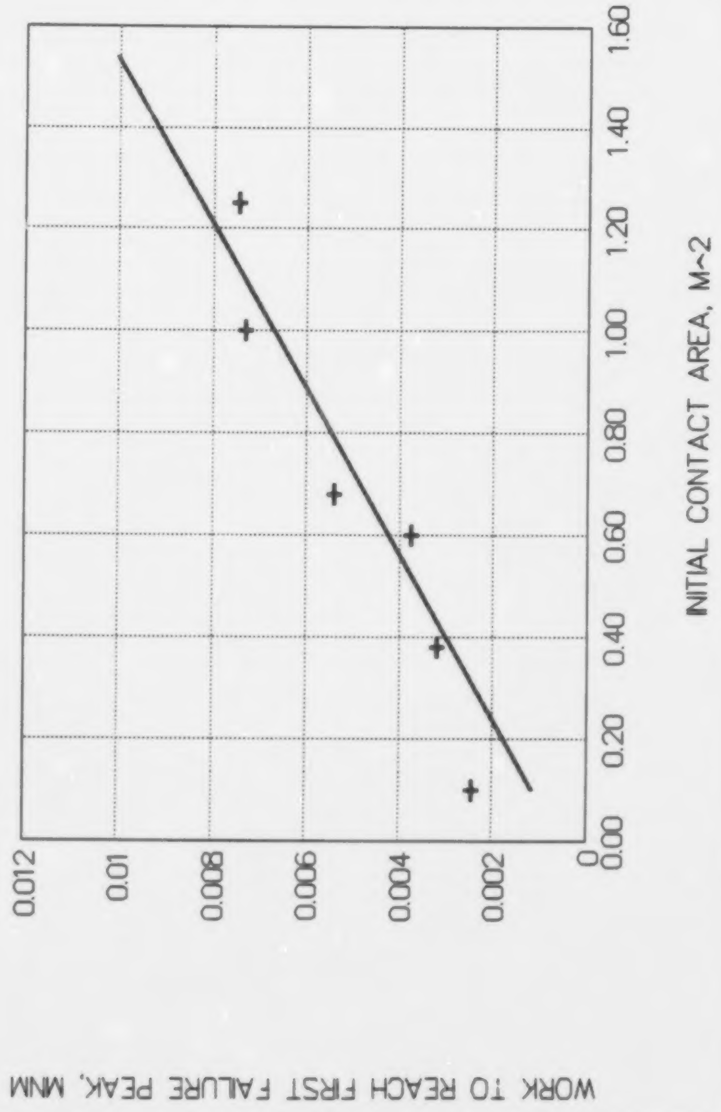
DEPENDENCE OF TOTAL IMPACT ENERGY ON THE INITIAL CONTACT AREA

Figure 5.6.2.



WORK TO FAIL ICE AND TO REACH PEAK LOAD

Figure 5.6.3.



WORK TO FAIL ICE (FIRST PEAK) AS A FUNCTION OF CONTACT AREA

Figure 5.6.4.

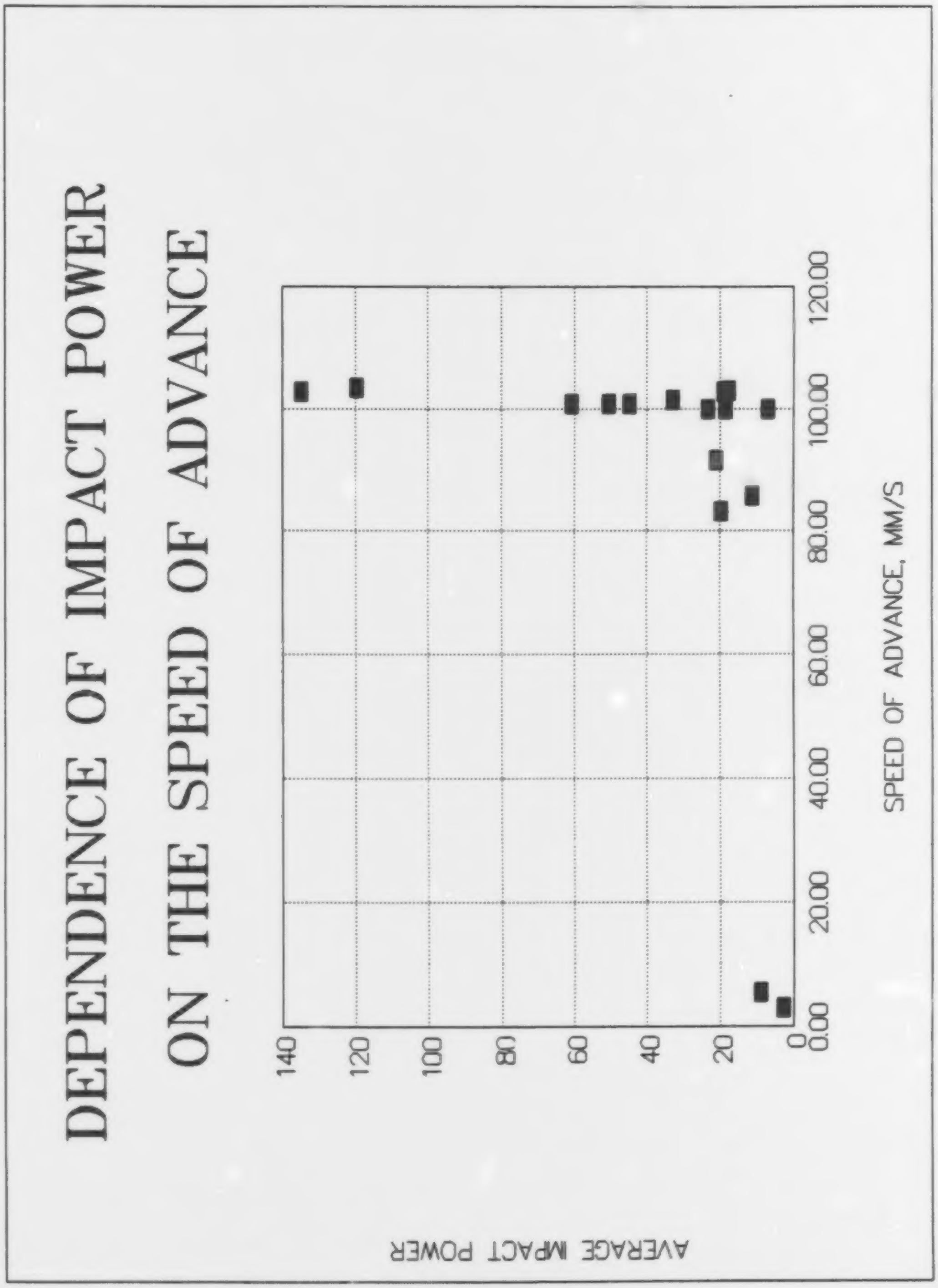

DEPENDENCE OF IMPACT POWER
ON THE SPEED OF ADVANCE
AVERAGE IMPACT POWER
140
120
100
80
60
40
20
0
0.00
20.00
40.00
60.00
80.00
100.00
120.00
SPEED OF ADVANCE, MM/S

TABLE 5.6.2.
TEST MAXIMUM STRAINS SQUARED

TEST NR	MAX LOAD	STRAIN^2 BR1	BR2	S1 TO S8
	MN	MICROSTRAINS^2		
1	0.66	260,100	672,400	280,900
2	0.53	504,100	705,600	476,100
3	0.53	592,900	810,000	592,900
4	1.03	1,440,000	122,500	1,166,400
5	0.37	202,500	57,600	202,500
6	0.57	129,600	518,400	230,400
7	0.37	211,600	360,000	
8	0.53	547,600	815,409	846,400
9	1.28	1,960,000	2,890,000	3,240,000
10	0.42	416,025		980,100
11	1.13	2,073,600	3,240,000	4,494,400
12	1.27	2,656,900	3,880,900	4,000,000
14	1.75	5,290,000	7,840,000	4,080,400
15	3.93	23,040,000	23,040,000	16,402,500
18	2.05	18,490,000	34,222,500	100,000,000
19	2.40	100,000,000	59,290,000	100,000,000
MAX	3.93	100,000,000	59,290,000	100,000,000
MIN	0.37	129,600	57,600	202,500
AVGE	1.18	9,863,433	9,231,021	15,799,533

Figure 5.6.5.

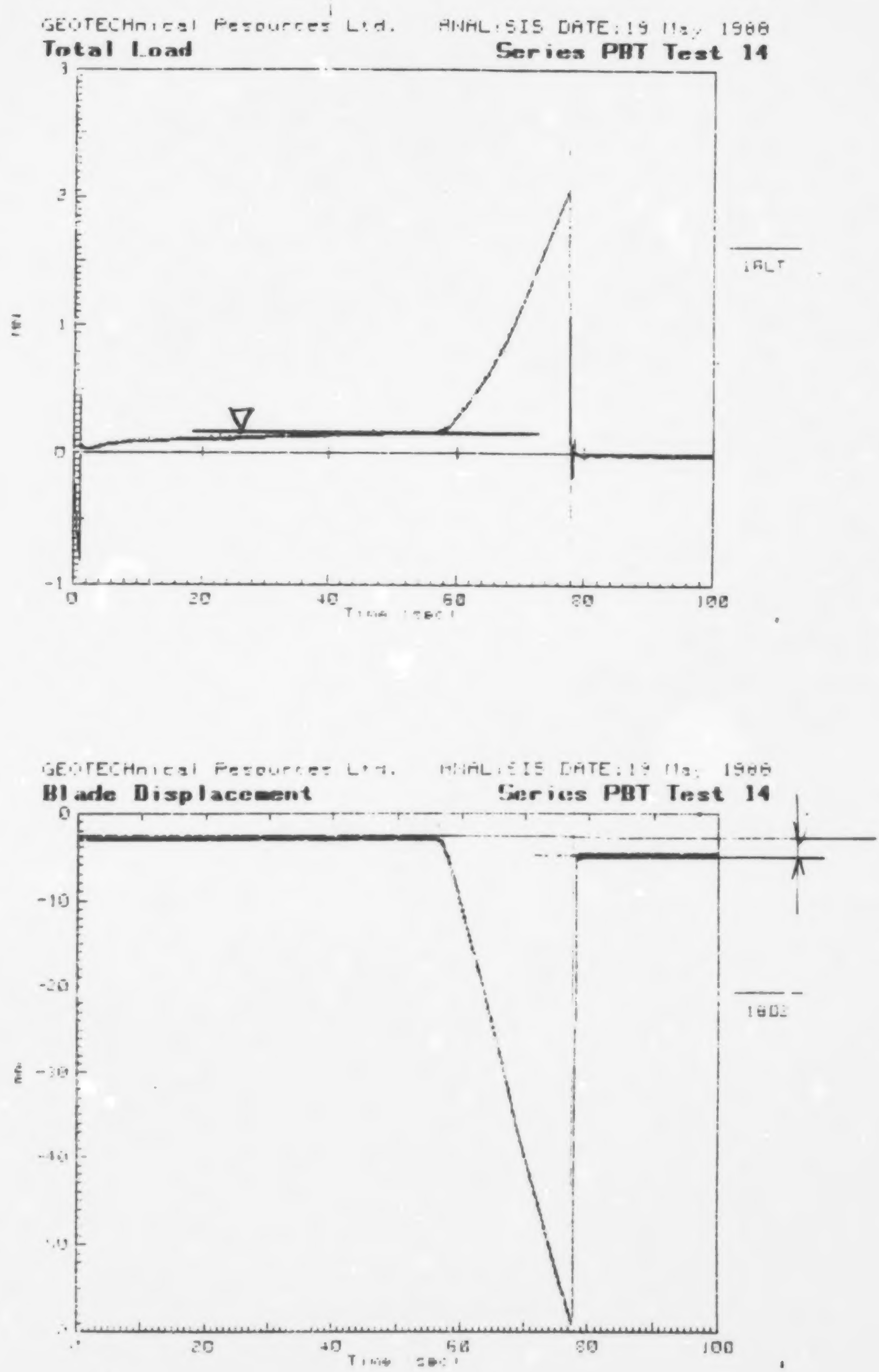

GEOTECHnical Resources Ltd.
ANALYSIS DATE:19 May 1988
Total Load
Series PBT Test 14
kN
3
2
1
0
-1
0
20
40
60
80
100
Time (sec)
1ALT
GEOTECHnical Resources Ltd.
ANALYSIS DATE:19 May 1988
Blade Displacement
Series PBT Test 14
mm
0
-10
-20
-30
-40
-50
20
40
60
80
100
Time (sec)
1BD2

Figure 5.6.6.

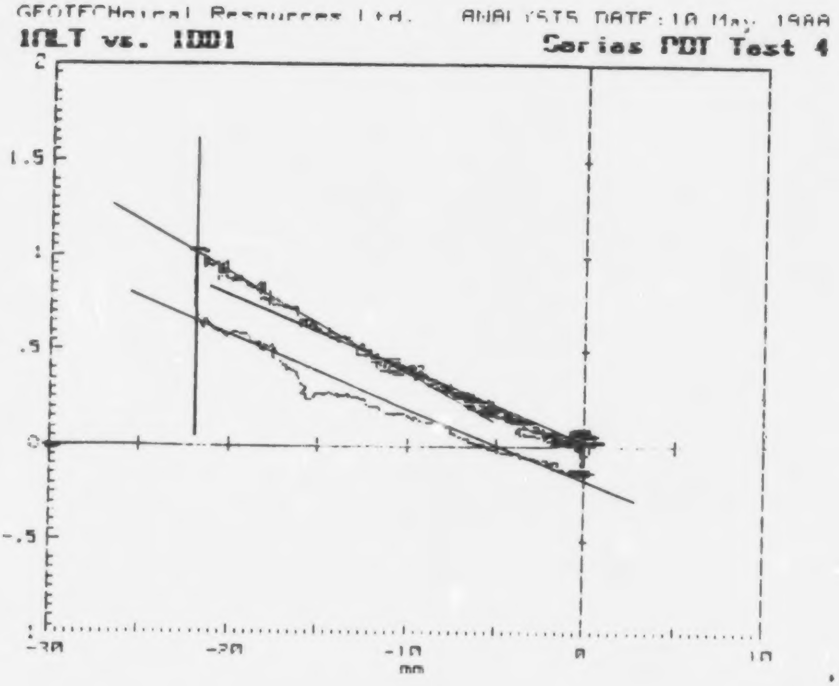

GEOTECHnical Resources Ltd.
ANALYSIS DATE: 10 May 1988
TILT vs. IDD1
Series PDT Test 4
2
1.5
1
.5
0
-.5
-1
kN
-30
-20
-10
0
10
mm

Figure 5.6.7.

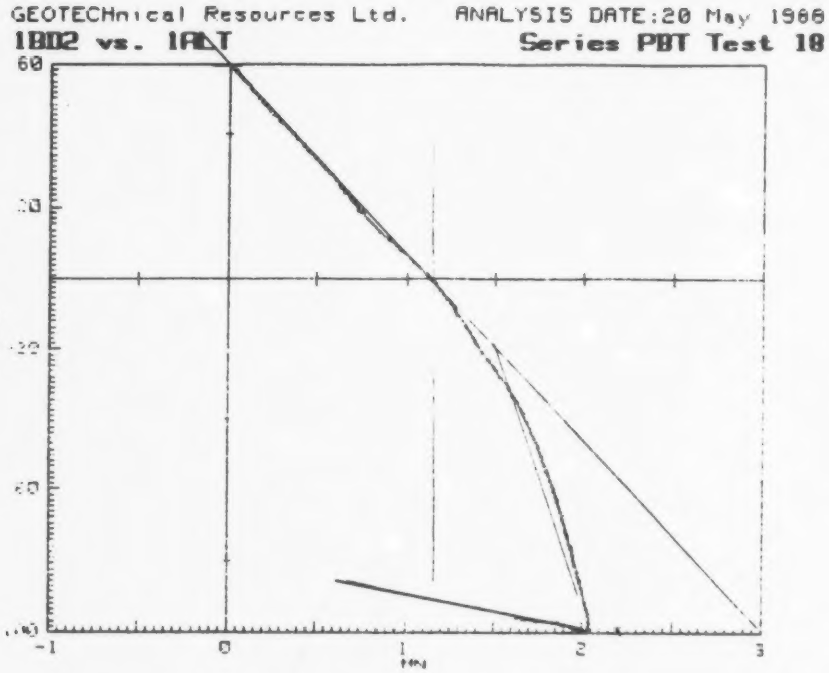

GEOTECHnical Resources Ltd.
ANALYSIS DATE:20 May 1988
1BD2 vs. 1ALT
Series PBT Test 18
60
20
-20
-60
-100
-1
0
1
2
3

Figure 5.6.8.

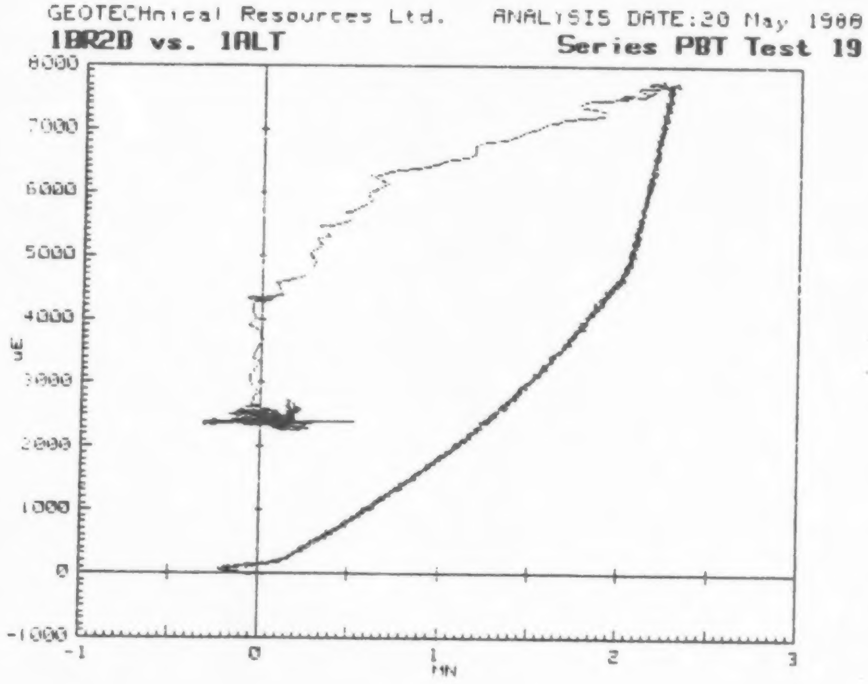
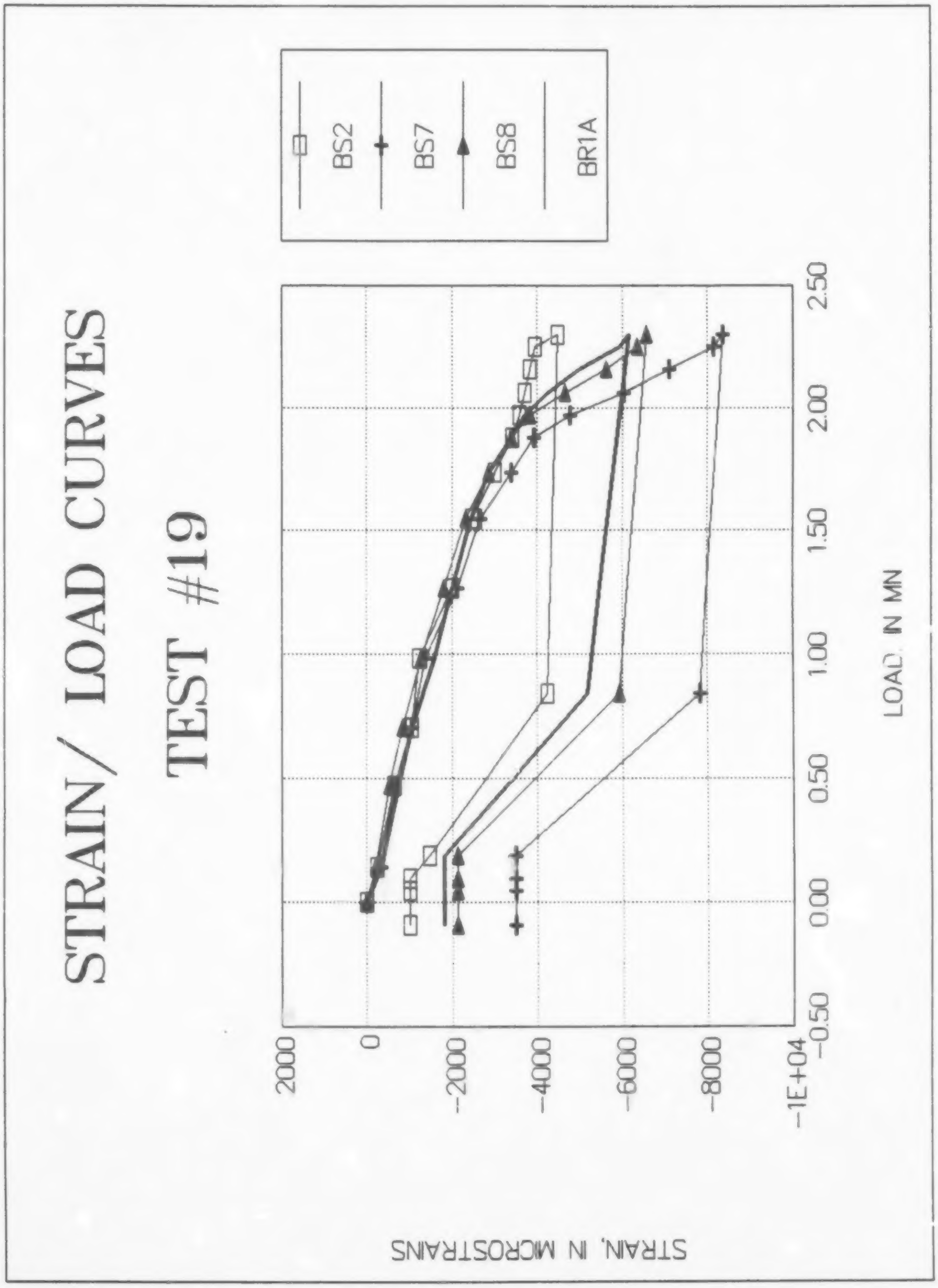

GEOTECHnical Resources Ltd.
ANALYSIS DATE:20 May 1988
1BR2B vs. 1ALT
Series PBT Test 19
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
uE
-1
0
1
2
3
MN

Figure 5.6.9.


STRAIN/ LOAD CURVES
TEST #19
BS2
BS7
BS8
BR1A
2000
0
-2000
-4000
-6000
-8000
-1E+04
-0.50
0.00
0.50
1.00
1.50
2.00
2.50
LOAD IN MN
STRAIN, IN MICROSTRAINS

6. COMMENTS ON THE ENGINEERING SIGNIFICANCE OF THE TEST RESULTS.

6.1 The main comments are:

* The blade of the **shrouded CPP propeller was found to be very strong in terms of the ultimate load** it was able to carry without complete destruction:

3.93MN.

* This is **more than twice** the amount stated as a blade collapsing load by the propeller manufacturer (1.838MN).

* At that load level, the blade residual deformation near the leading edge was significant (40mm), but localized, and the **blade was considered to be still operational**, perhaps at reduced RPM.

* While the load needed to completely destroy the blade (bend it, say, 45 degrees) **would be of the order of 16 MN**, the blade would bend away from the ice in a ductile fashion.

* The tests have shown (test#19) that the higher the degree of the bend, **the less blade area is presented to the ice**, ergo the deformation of the blade are of a **self- protecting** character.

* All blade deformations were of **a ductile character,** no cracks were found in the deformed areas. This type of damage is **easy to repair.**

* The **onset of the plasticity on the blade** was found to be **low (approximately 1MN),** especially at thick sections.

* Although a number of high loads were applied there was **no evidence of blade brittle cracking whatsoever.**

* This means that **the existing crack near the blade root** was probably caused by the **cyclic loading of low amplitude** (hydrodynamic and inertial loads) and not by the individual high loads coming from a direct contact with the ice. The crack is located on the compression side.

* The issue of the **blade suitability for service** is therefore not based on the ultimate load it can carry, but on the **geometry of the deformed blade** and its influence on the blade performance and vibrations levels in that condition.

* Therefore this is an **issue of the stiffness** of the blade sections (governed by the section moment of inertia), **rather than the strength** of it (governed by the section modulus).

* High speed loads yielded lower blade interaction forces

than the low speed ones.

* Low speed interactions produced highest blade loads. This proves that the **speed of the backing ship is not the main factor** in determining the magnitude of the ice/blade interaction loads.

* The energy needed to develop the forces of the order of 4MN on the blade is **a small fraction** of the ship's energy.

* Ice failure forces, during the brittle tests are small fractions of the total force needed to compress and extrude the broken ice. In this type of tests, the gap between the unbroken ice and the confinement of it are important parameters to consider.

* **The onset of the plasticity of the blade is low,** particularly at the thick sections. This means that even small loads can cause small plastic deformations of the blade which, in time, can accumulate to a degree requiring repairs.

* The blade can **withstand stresses of the order of 290 MPa** (45% of UTS) with only local material flow.

* The residual plastic deformations are small, as the blade material is pulled back into shape by the surrounding elastic deformation fields.

* The existing models of ice/propeller blade interactions do not reflect the results of the tests performed. New developments are needed in this field.

* Blade response is an important factor in determining the ice/blade interaction pressures.

* The envelope of the peak pressures recorded during the test,which were recorded at various pieces of equipment, show a characteristic pressure/area decay curve.

* The peak pressure of 29 MPa occurred during the ductile tests. These tests show steady and stable pressure /load correlation, unlike the brittle tests.

* More than half of the strain energy of the blade goes into the plastic deformation, for the example examined. This shows that the plasticity of the blade is another blade protection mechanism and it should be considered in modeling of the blade response to high loads.

* In overall perspective the blade material performed well, but the **increase of yield strain of the thick sections would much improve the blade performance** at high loads.

6.2 A brief discussion of the effects of the bent blade on the magnitude of the centrifugal loads and moments.

Take a flat and slender plate rotating with a certain RPM around its base. If the segment of this plate is bent 90 degrees, the centrifugal force developed about the axis of rotation will be different from the force acting on the straight blade-plate. The ratio of these forces in straight and bent condition is shown in Figure 5.7.1.
The following conclusion is immediate:

For the bends of up to 30% of the blade length, the change of the centrifugal force is within 10%. Thus this effect is negligible, even for the 90 degree bends.

In addition, there is a restoring centrifugal moment developed at the knuckle which lowers the stresses at that point and tries to straighten the blade out to its original shape. This moment can be expressed as:

$$BMc = BMC * m * Vtip^2 \qquad \text{.........................5.7.1}$$

where:
m is the mass of the flat plate,
Vtip is the velocity of the tip of the blade, and
BMC is the bending moment coefficient depending on the geometry of the blade and the bend.

Figure 5.7.2. shows the value of the bending moment coefficient at the knuckle, as a function of the angle of the bend and the length of the bend section. The graph is valid for the flat and slender plate/blade.

Taking, for example Vtip = 37m/s, m = 2400kg, l/L =.7 and the angle of bend as 90 degrees, we obtain:

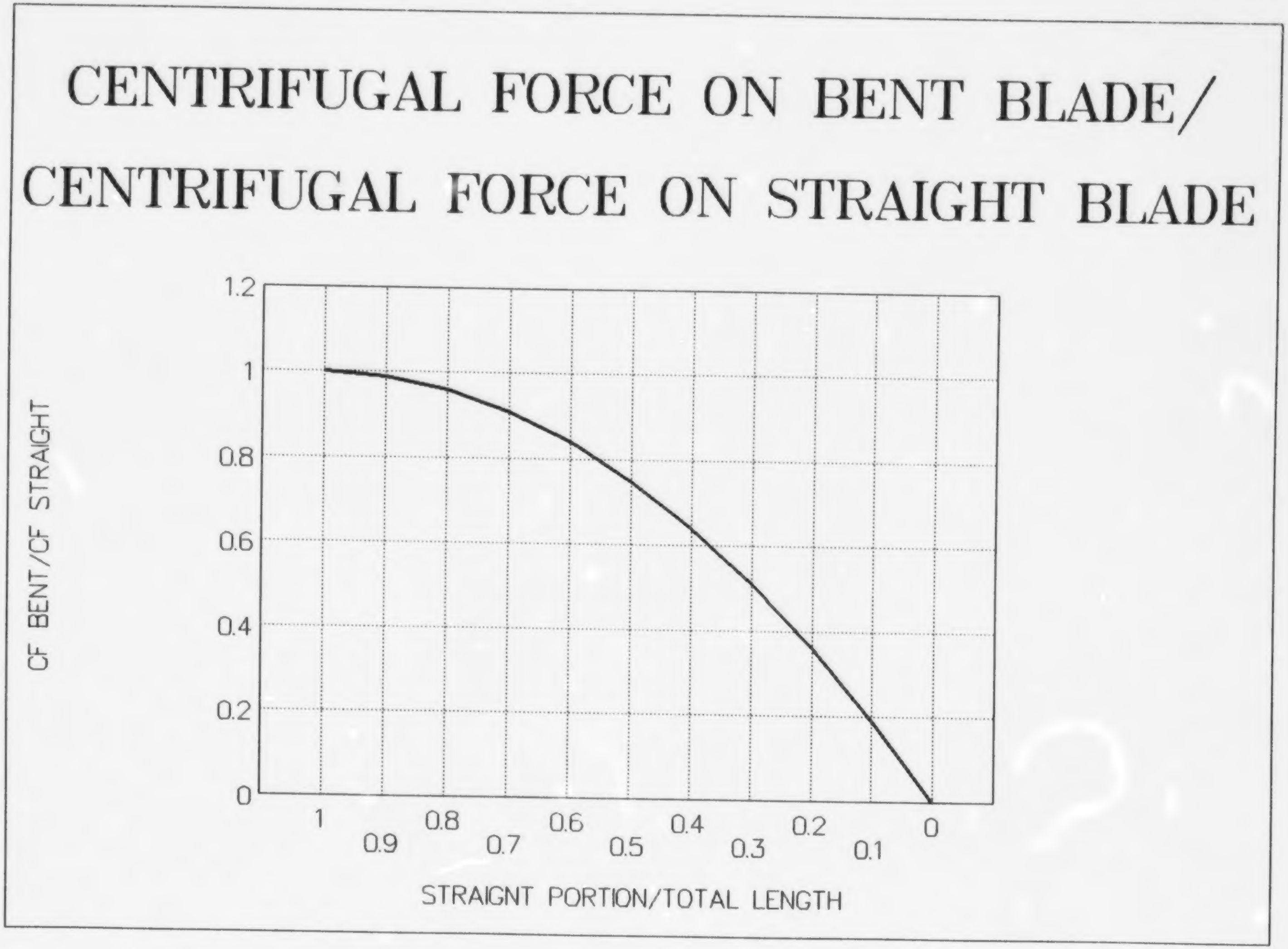
$$BMc = 0.031 * 2,425 * 37^2 = 103 \text{ kNm}.$$

This restoring moment is comparable with the bending moments induced by the hydrodynamic loads.

Consequently we can conclude that:

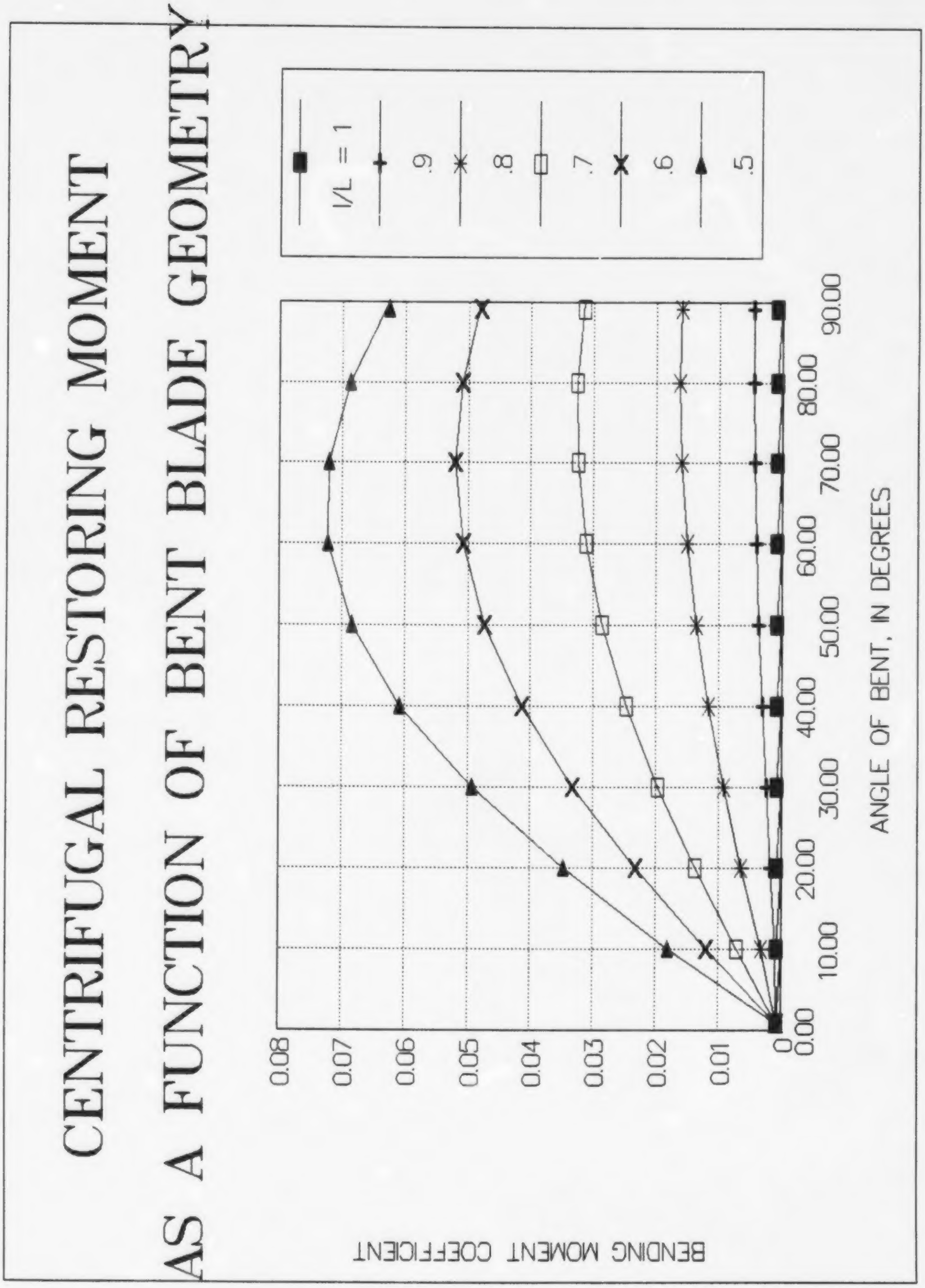
- The bending of the blade (within the limits stated) does not lead to a significant change of the centrifugal forces and the consequent vibrations.
- The restoring centrifugal moments are high, hence the stresses are low.
- This shows that the centrifugal aspects and stress aspects of the bent blade are of no great importance.

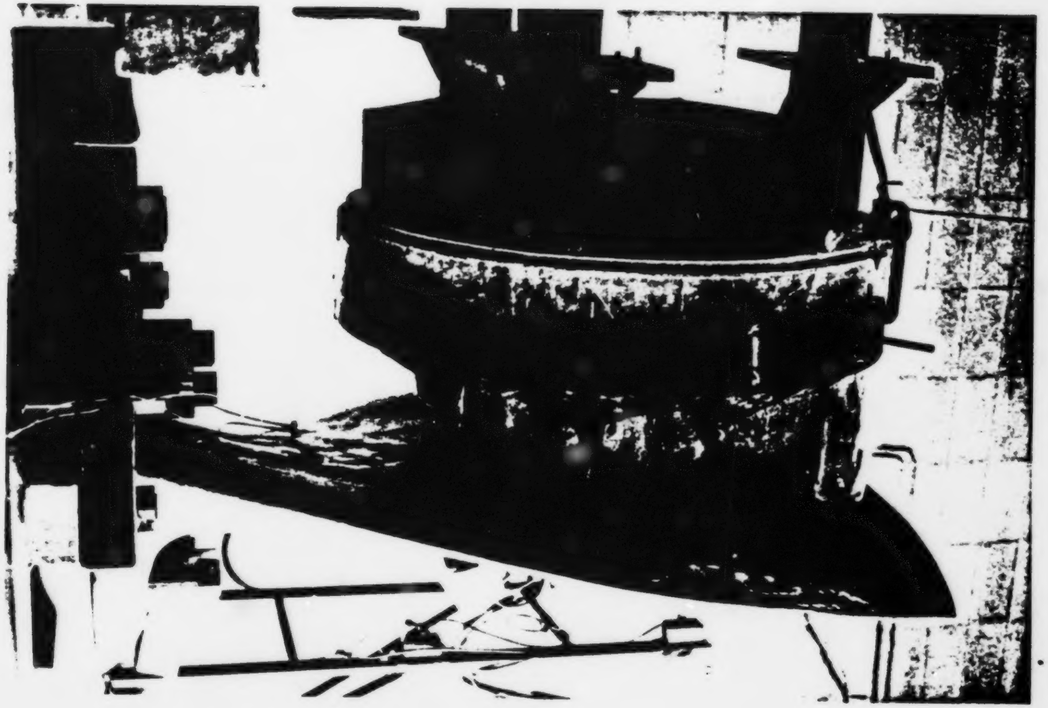
FIGURE 6.1



CENTRIFUGAL FORCE ON BENT BLADE/
CENTRIFUGAL FORCE ON STRAIGHT BLADE

FIGURE 6.2


CENTRIFUGAL RESTORING MOMENT
AS A FUNCTION OF BENT BLADE GEOMETRY
BENDING MOMENT COEFFICIENT
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
ANGLE OF BENT, IN DEGREES
l/L = 1
.9
.8
.7
.6
.5



7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

The main conclusions of the data analysis are:

ICE/BLADE INTERACTION

Two main types of ice/blade interaction were identified:

brittle, and
ductile.

Brittle type of interaction is characterized by the following phases:

initial loading
ice failure
crushed ice extrusion
relaxation

Post crushing extrusion forces are dependent on the ice confinement geometry (the gap between the blade and the bucket), and can reach much higher levels than the ice failure loads.

Post failure ice extrusion loads are proportional to the ice failure loads.

Highest loads on the blade were registered during the slow speed tests.

Point of load application on the blade changes during the interaction.

Center of the blade attracts more load than the edge.

The maximum pressure registered on the blade was 29.0 MPa on the area of 0.0044m^2. The peak pressure envelope /area curve shows the characteristic decay.

The average of the maximum pressures registered during the tests was 3.26 MPa, which is comparable with the results of the full scale tests of sea ice in crushing mode.

The peak pressures take place at the middle of the apparent contact area.

For the brittle tests, the peak pressures were not occurring at the instance of the peak loads.

There is a linear correlation between the peak pressure and the peak load.

Pressure buildup takes longer than the pressure relief.

Pressure histories are often not compatible with the load histories during the brittle tests, while they are compatible during the ductile tests.

The pressure area has a distributive property, that is the high pressure in one area means that there is a low pressure in the other.

Ice failure energy is an order of magnitude smaller than ice extrusion energy.

Timber/blade interaction was very similar in nature to the ductile ice/blade interaction.

BLADE RESPONSE

There is a strong correlation between the maximum blade load and the maximum blade displacement.

The maximum blade displacement of 186mm was recorded at the upper corner near the leading edge.

The maximum strains recorded were 0.01 strains which is 5 times the strains causing yield of the material.

The relationships between the strains at the tension and compression sides of the blade are not linear.

Displacements needed to cause some plastic deformation were:

5mm near the blade root, at the centerline,
20mm near the center of the blade, and
57mm near the leading edge.

The behavior of the material is predominantly linear elasto-plastic in thin areas, and strongly nonlinear elasto-plastic in thick areas.

The blade withstood, with some plastic flow, surface stresses of the order of 290 MPa.

The yielding of the material started at a stress level of 251MPa, at the location tested, which is consistent with the manufacturer's numbers.

The strains near the midspan of the blade were generally the highest, for the conditions tested, which confirms the blade-cantilever beam analogy.

Small plastic deformations began already at a load level of 0.5MN.

The tests showed that the blade can withstand loads of the order of 4 MN with the limited plastic deformation (40mm).

There was no evidence of material surface cracks, similar to that existing at the root.

The maximum load the blade withstood (3.93MN), with limited deformation, was over twice the maximum blade destruction load specified by the manufacturer for the central load, and 3.5 times the destruction load applied at the leading edge.

Maximum strains of 10,000 microstrains were recorded during the tests, which are 5 times the strain level causing the yield of the material.

The maximum energy expended during the tests was 0.352 MNm.

The work needed to fail ice initially is an order of magnitude smaller than the total work spent during the interaction.

Work needed to fail ice is proportional to the initial contact area.

For the ductile tests, most of the energy (71%) went into the blade.

For the large deformation tests, most of the strain energy (75%) went into the plastic deformation of the blade.

At the load level of 1 MN there is a significant plastic deformation taking place, at many gauge locations.

For the locations examined, the residual plastic strain was 25% to 42% of the maximum strains recorded.

7.2 Recommendations

We recommend that:

1. *An analysis of the test data with respect to its application to ASPPR regulations (strength/stiffness issue) pertaining to the propeller blade strength criteria is carried out.*
2. *A comparison of the test data with the full scale ice/propeller interactions is carried out for the purpose of shedding some light on the nature of propeller damages.*
3. *A material oriented experimental study is carried out to determine the plastic, ultimate and fatigue properties of various propeller blade materials in order to establish the causes of the existing blades failures.*
4. *A model of ice/blade interaction is developed and implemented, reflecting the wealth of new information collected.*

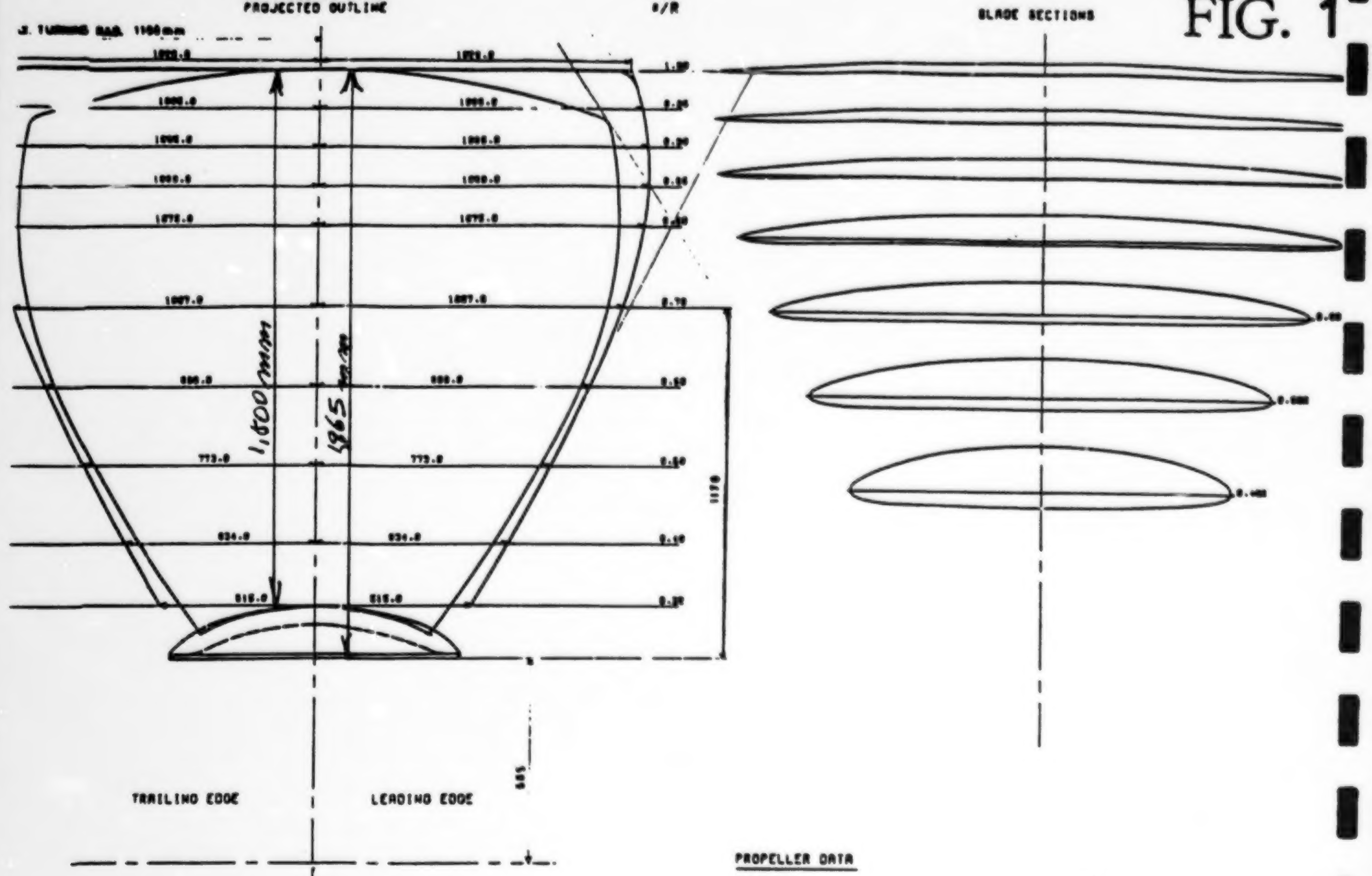
8. REFERENCES

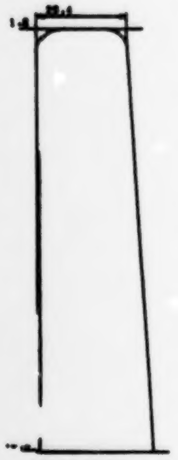
1. *Full Scale Tests on the Response of Ice strengthened Propeller Blade to Ice Loads, Volume 1, Geotechnical Resources Ltd.1989.*
2. *MV Canmar Kigoriak Propeller Characteristics, LIPS Propeller Works. Published with the permission of Dome Petroleum Ltd.*
3. *Elasticity, Fracture and Flow, J.C. Jaeger, Science Paperbacks,1969.*
4. *Robert LeMeur ice/propeller interaction, 1985 Final Report. TP#6176/77/78.*

APPENDIX A: GEOMETRY OF THE BLADE

B-KG-848-09

FIG. 1


EXPANDED OUTLINE
PROJECTED OUTLINE
r/R
BLADE SECTIONS
J. TURNING RAD. 1160mm
1.00
0.95
0.90
0.85
0.80
0.70
0.60
0.50
0.40
0.32
1890.0
1895.0
1075.0
1087.0
880.0
773.0
634.0
515.0
1,800 mm
1965 mm
1170
0.400
585
TRAILING EDGE
LEADING EDGE



DETAIL BLADE TIP
SCALE 1:1.0

PROPELLER DATA

DIAMETER	5300 MM	
HUBDIAMETER	1700 MM	
HUBTYPE	4C 178H	
PITCH. —	5088 MM	
NUMBER OF BLADES	4	
DIRECTION OF ROTATION	LEFT-HANDED	(DRAWN RIGHT HAN
EXPANDED BLADE AREA RATIO	0.5904	
MATERIAL	CUNIAL	MASS 2670 KG
MINIMUM TENSILE STRENGTH	647 N/MM²	
MINIMUM ELONGATION	20 %	
POLAR MASS MOMENT OF INERTIA	— 28700. KGM²	
ENGINE OUTPUT	12800. KW	
PROPELLER REVOLUTIONS	135.4 RPM	
CLASSIFICATION	LRS.1A SUPER/CAN.ARCTIC 3	

PITCH SELECTED FOR :1742. KW 135.4 RPM AT TRIAL CONDITION.

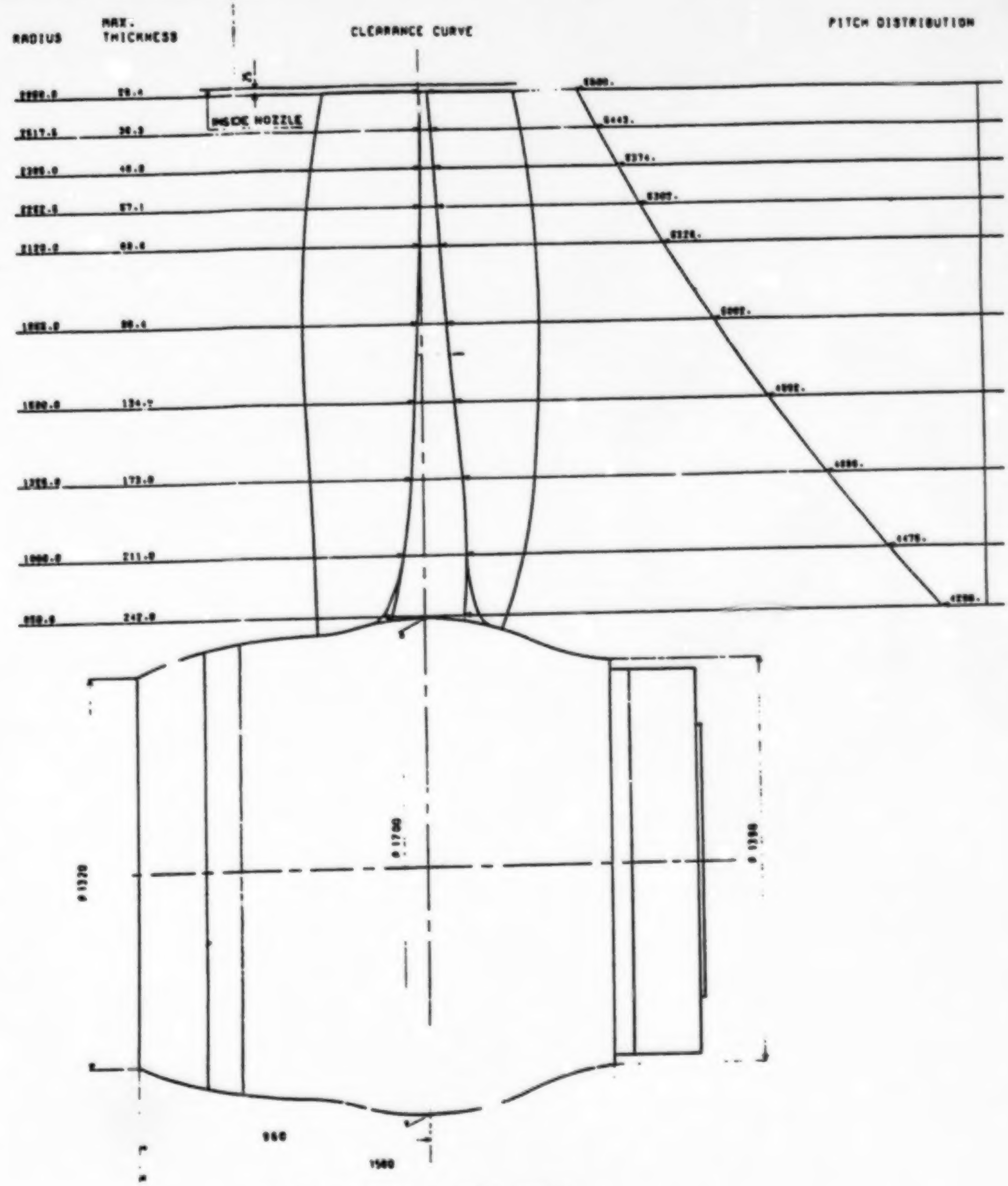
ALL BLADES FINISHING TOLERANCES IN ACCORDANCE
WITH I.S.O R484 MAY 1968 CLASS I

PITCH AT M.C.R.	
r/R	PITCH
1.00	6630.0
0.95	6710.0
0.90	6505.0
0.85	6450.0
0.80	6330.0
0.70	6062.0
0.60	5795.0
0.50	5495.0
0.40	5193.0
0.35	5035.0
0.32	4940.0

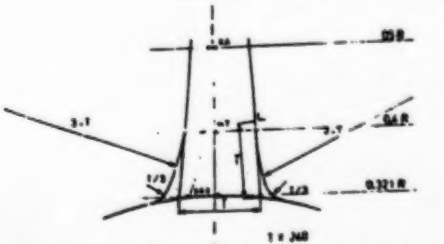
B-KIG-848-

C.P.PROPELLER FOR
ICE BREAKING TUG NB. 1132

LIPS [illegible] LTD

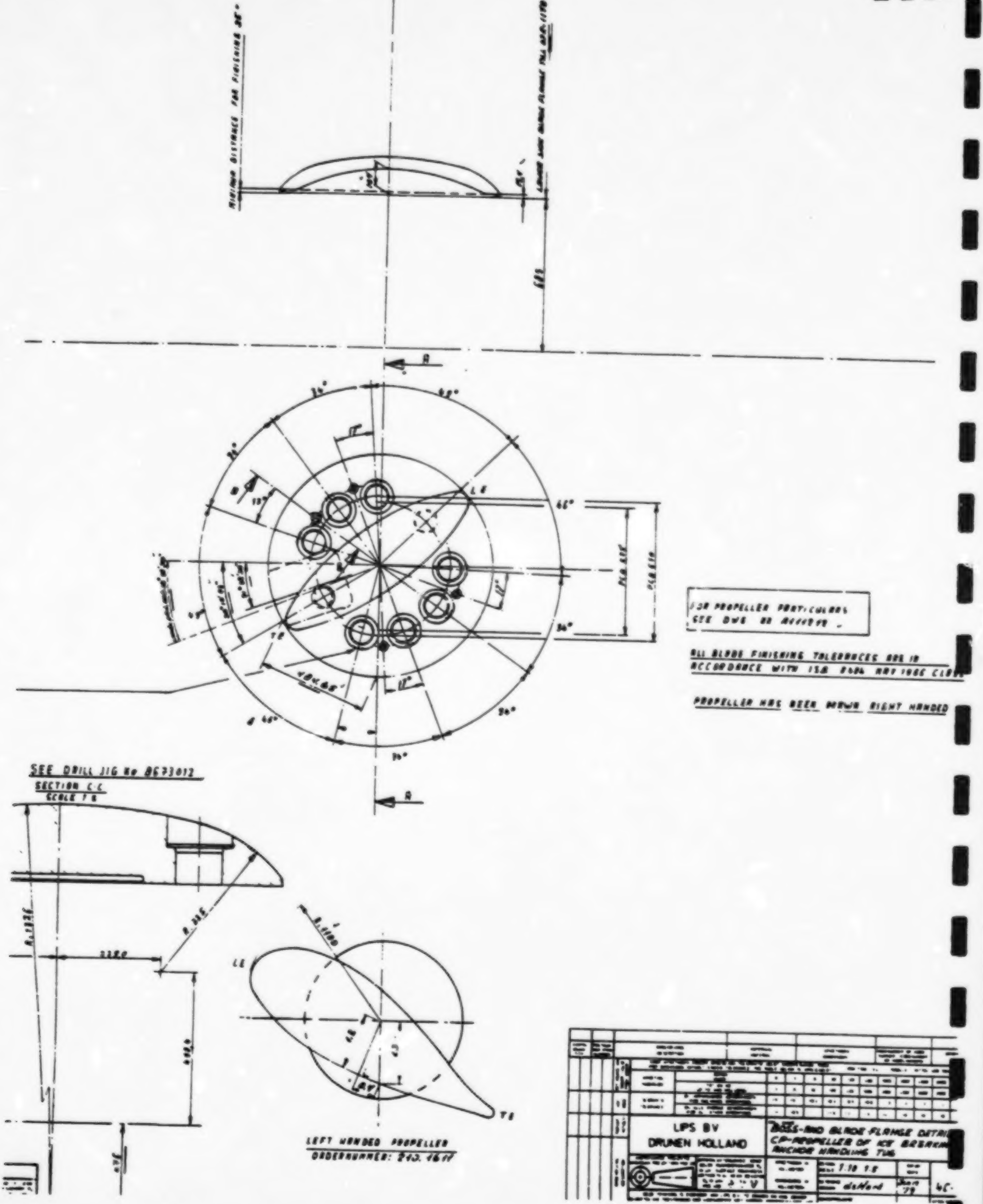

RADIUS
MAX. THICKNESS
CLEARANCE CURVE
PITCH DISTRIBUTION
INSIDE NOZZLE
2650.0
29.4
2517.5
38.3
2385.0
48.0
2252.5
57.1
2120.0
68.6
1855.0
88.4
1590.0
134.7
1325.0
173.0
1060.0
211.0
850.0
242.0
5500.
5443.
5374.
5307.
5226.
5062.
4892.
4696.
4475.
4296.
Ø 1320
Ø 1700
Ø 1290
960
1500

NOTE: FOR HUB DETAIL SE. DWG NR A111210


3.7
3.7
1/3
1/3
0.4 R
0.321 R
1 = 240

DETAIL BLADE ROOT FILLETS AND RAKE

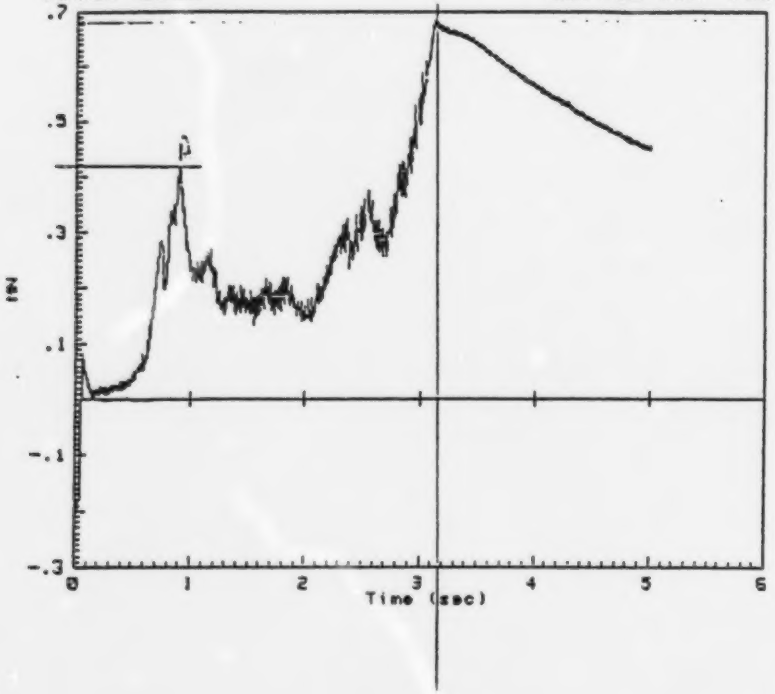
FIG.


MINIMUM DISTANCE FOR FINISHING 25°
A
LE
TE
40°
36°
17°
15°
SEE DRILL JIG No 8673012
SECTION C-C
SCALE 1:8
2220
LE
TE
LEFT HANDED PROPELLER
ORDERNUMMER: 213.1611
FOR PROPELLER PARTICULARS
SEE DWG
ALL BLADE FINISHING TOLERANCES ARE IN
ACCORDANCE WITH ISO
PROPELLER HAS BEEN DRAWN RIGHT HANDED
LIPS BV
DRUNEN HOLLAND
BOSS- AND BLADE FLANGE DETAI
CP-PROPELLER OF ICE BREAKIN
ANCHOR HANDLING TUG
1:10 1:8
de Hond
46.

APPENDIX B: TEST LOGS

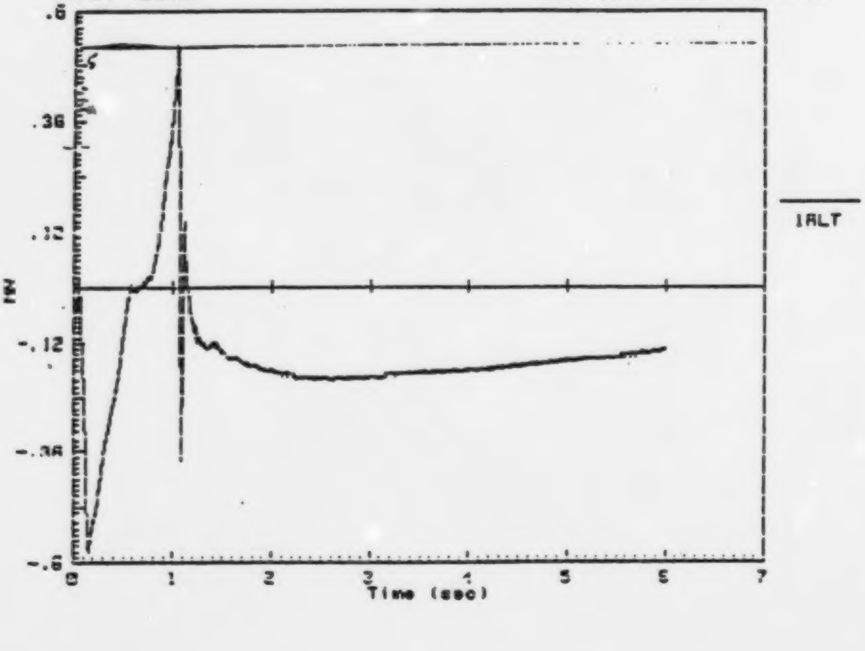
GEOTECHnical Resources Ltd. ANALYSIS DATE: 6 May 1988

Total Load **Series PBT Test 1**

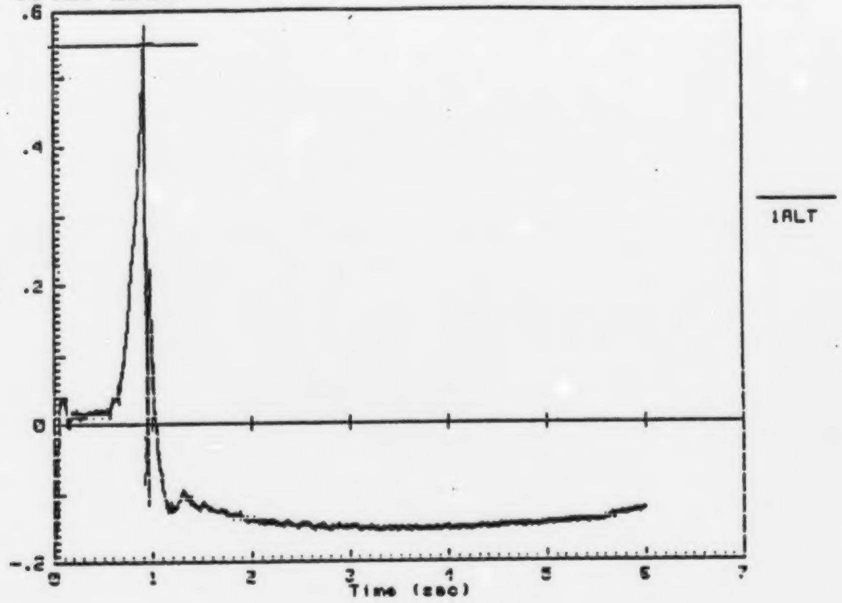


EOTECHnical Resources Ltd. ANALYSIS DATE: 10 May 1988

tal Load **Series PBT Test 2**

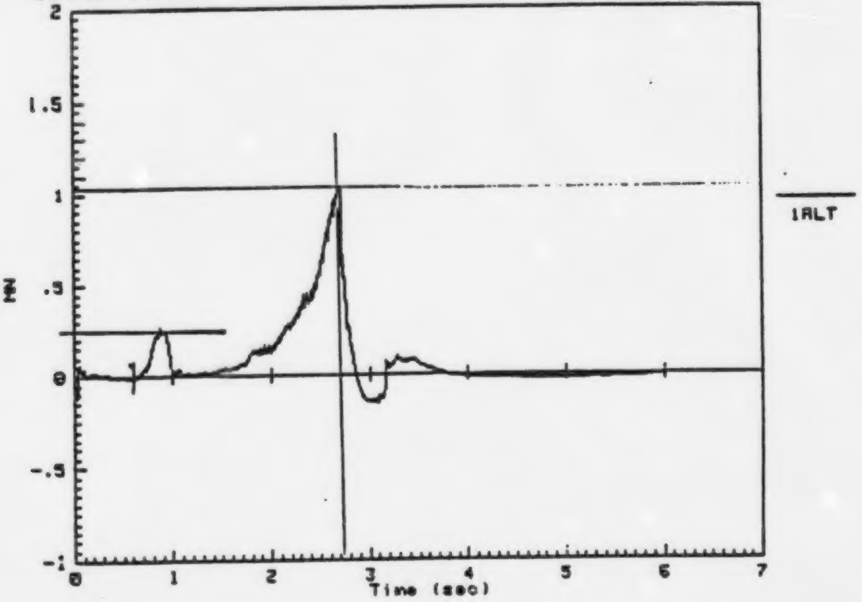


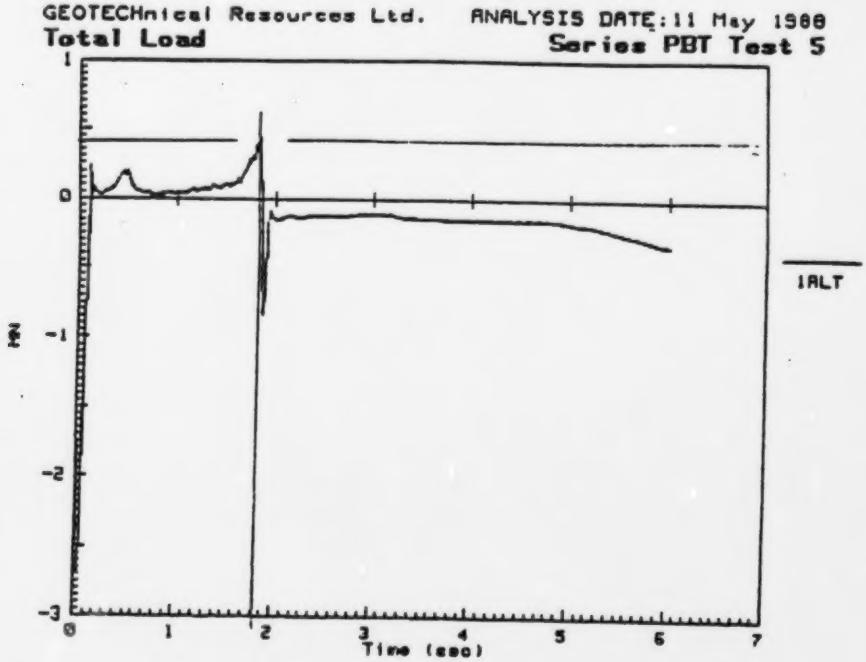
Total Load **Series PBT Test 3**



GEOTECHnical Resources Ltd. ANALYSIS DATE:18 May 1988

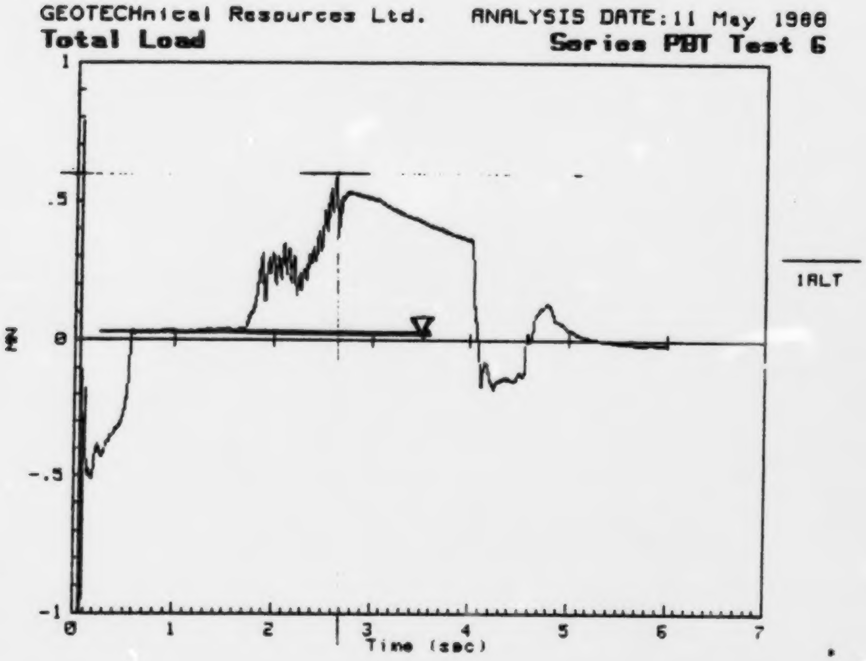
Total Load **Series PBT Test 4**




GEOTECHnical Resources Ltd. ANALYSIS DATE: 11 May 1988

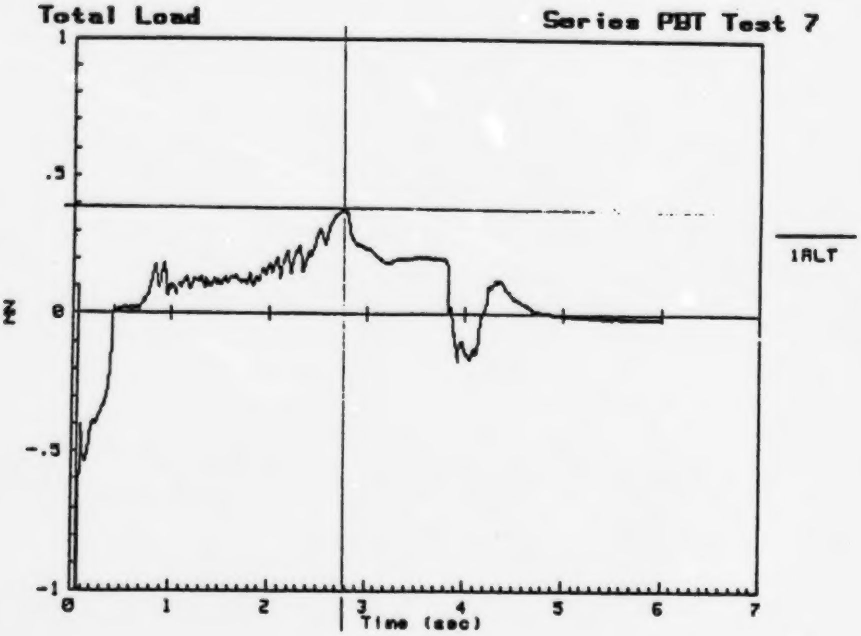
Total Load

Series PBT Test 5

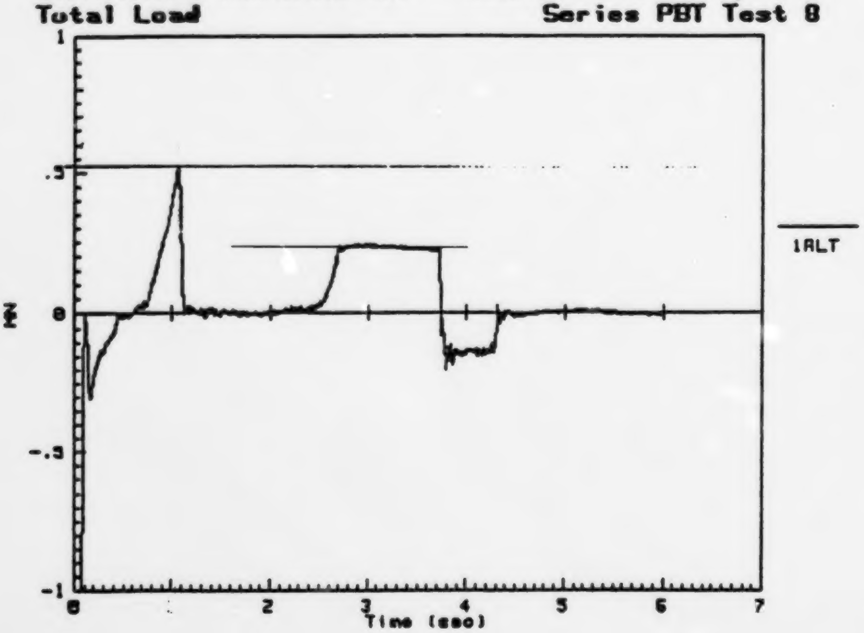

GEOTECHnical Resources Ltd. ANALYSIS DATE: 11 May 1988

Total Load

Series PBT Test 6

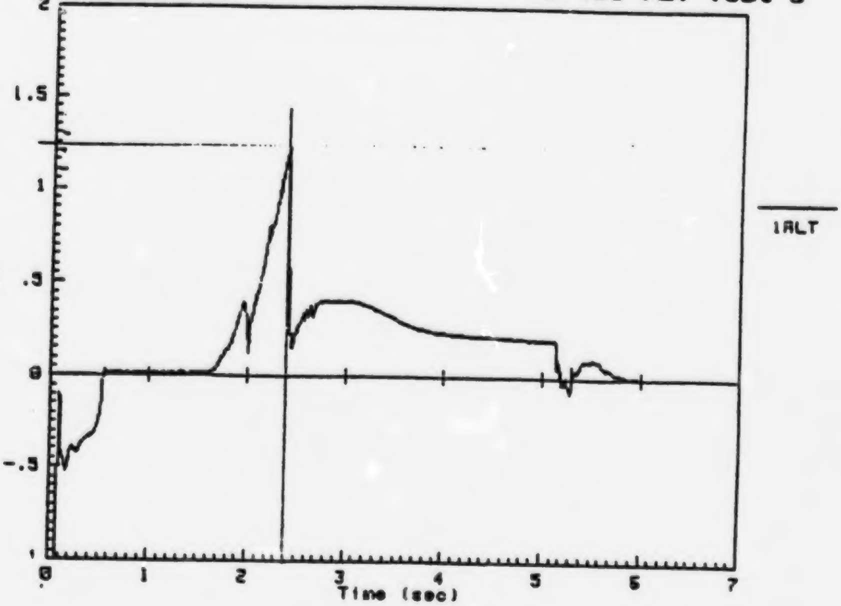


GEOTECHnical Resources Ltd. ANALYSIS DATE:16 May 1988

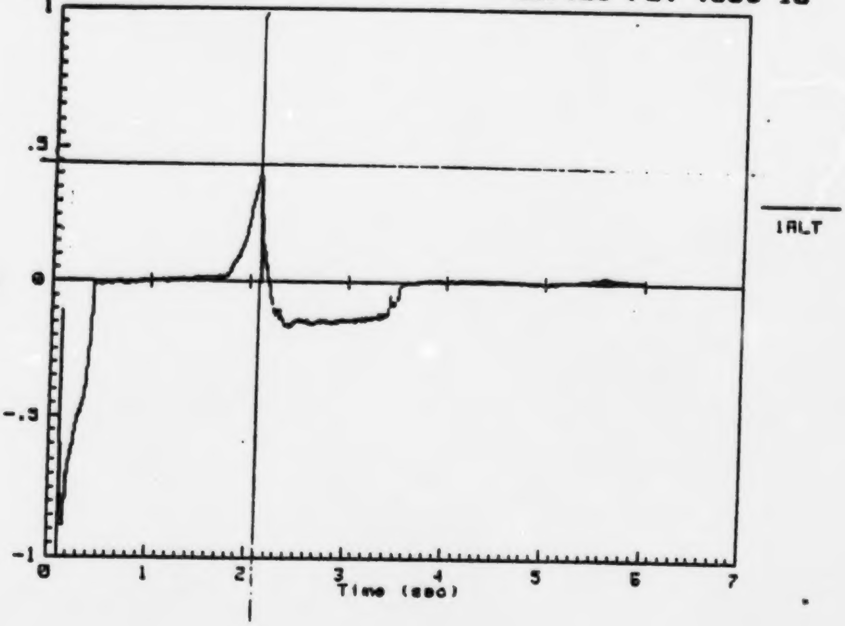


GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

Total Load **Series PBT Test 9**

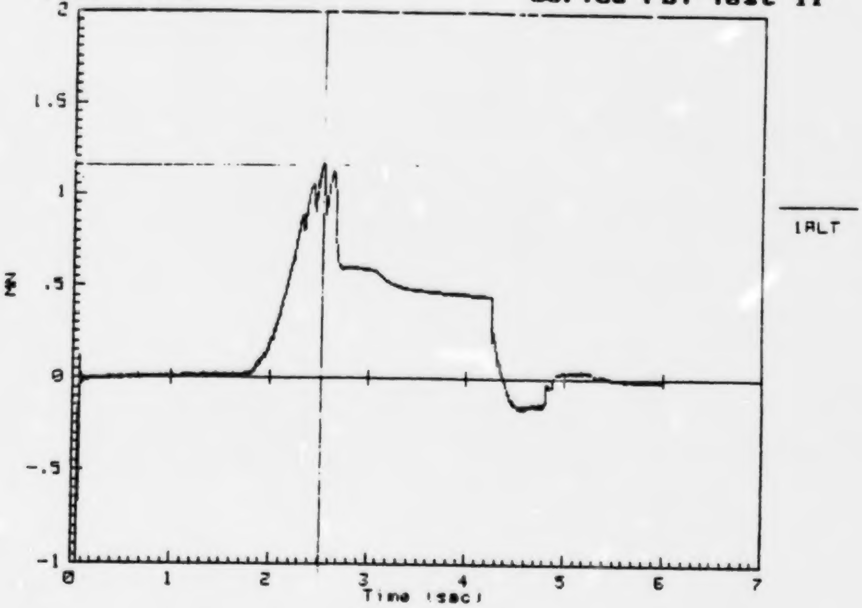


Total Load **Series PBT Test 10**

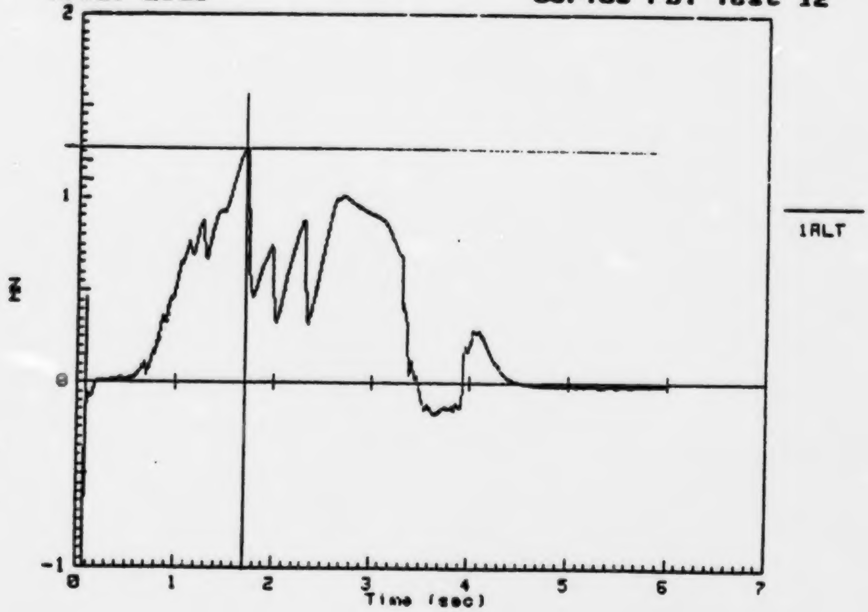


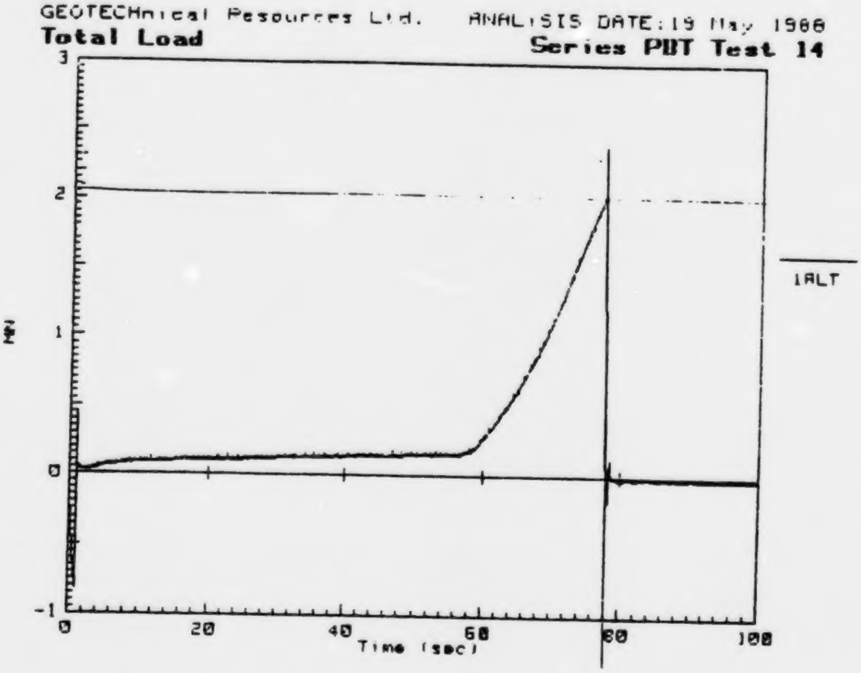
GEOTECHnical Resources Ltd. ANALYSIS DATE:17 May 1988

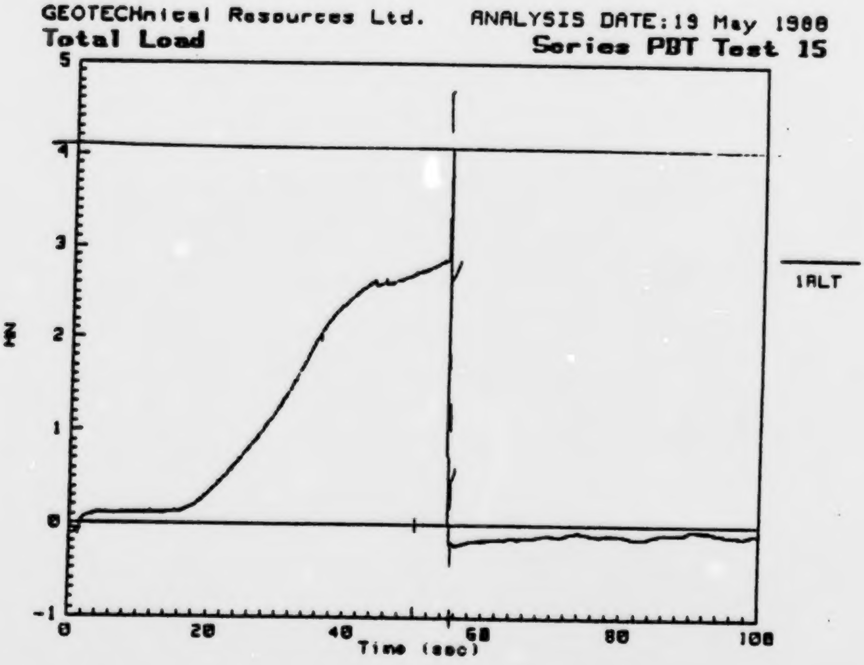
Total Load **Series PBT Test 11**



Total Load **Series PBT Test 12**

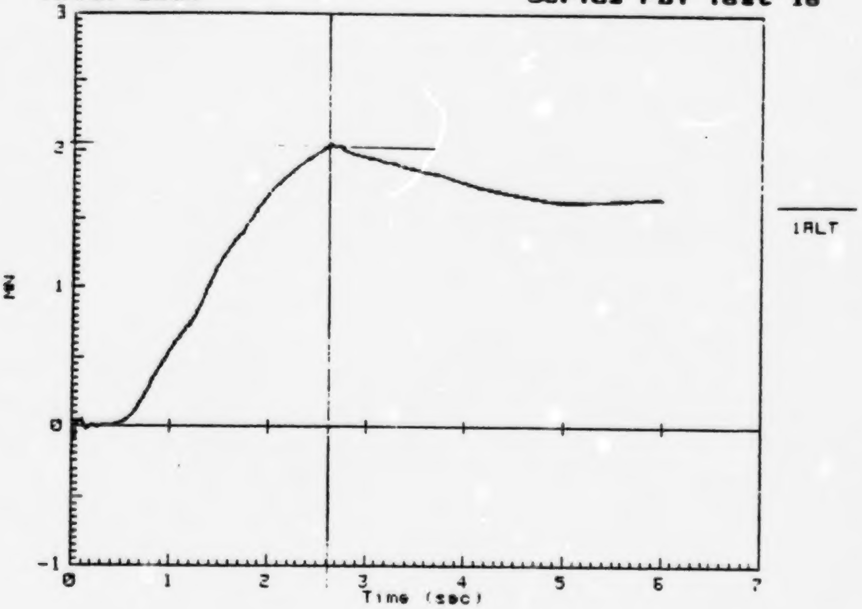



GEOTECHnical Resources Ltd.
ANALYSIS DATE:19 May 1988
Total Load
Series PBT Test 14
MN
3
2
1
0
-1
0
20
40
60
80
100
Time (sec)
1ALT


GEOTECHnical Resources Ltd.
ANALYSIS DATE:19 May 1988
Total Load
Series PBT Test 15
MN
5
4
3
2
1
0
-1
0
20
40
60
80
100
Time (sec)
1ALT

GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

Total Load **Series PBT Test 18**



GEOTECHnical Resources Ltd. ANALYSIS DATE:20 May 1988

Total Load **Series PBT Test 19**